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The Institute of Vitreous Enamellers

The Welsh Engineers' and Founders' Association

and

The Foundry Trades' Equipment and Supplies Association

Institute of British Foundrymen

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Progress Reports

At this period of the year quite a number of research organisations make known the progress they have achieved during the preceding twelve months. The most important, of course, is that of the National Physical Laboratory, and in this case it takes the form of an inspection by the General Board. In reality, this means that some 1,500 industrialists and technicians are invited to view as many of the buildings and exhibits as time will allow. Obviously, only a fraction of the work in progress can be inspected. Moreover, but few of the exhibits are self-explanatory, and to listen to the story as to why it takes three months to prepare a standard weight for the use of the New Zealand authorities is so fascinating that more time is occupied than would be credited. Again, the work being done in a small outbuilding of tunnel section was not obvious until it was explained that the white ceiling represented the sky, and the central dividing wall was supposed to be a street lined with tall buildings. Then, at ground level, is a toy-like house to which is fitted various types of windows and interior decorations. The object of the experiments then became obvious—that of measuring the amount of light entering the rooms under varying conditions.

The organisation at Teddington is such that four walls carrying the name of a department do not signify that therein is to be found all the work classifiable under that designation. For instance, metallurgical researches, at least so far as industry understands them, are by no means confined to Dr. Desch's department, for in the Engineering Department a large amount of creep testing is being undertaken. It is, of course, essential that the Laboratory constructs much of its own apparatus, but unlike most home-made contraptions, that in use at Teddington carries a finish of a very high order and often equal to those available on the open market. With the exception of magnesium alloys, there is not much work at the moment going forward of direct interest to the foundry. We noted, however, that increased attention is being paid to powder metallurgy.

Another progress report of interest to the foundry industry is that issued by the Institute of Welding. It discloses a very ambitious programme fashioned on industrial rather than academic lines. The section which has major interest for our readers is that devoted to the welding of cast iron. The commercial importance is initially recognised and a *questionnaire* has been sent to a number of foundries. From this it has been learnt that the following troubles are experienced in practice:—Unmachinable welds; cracking in the deposit or away from it; general unsoundness, and lack of adherence. The work to be undertaken will simulate practice by utilising heavy jigs for restraining movement. The B.C.I.R.A. laboratories at Birmingham will undertake the actual carrying out of the tests. The hope is expressed that the ultimate result of this work will be to dispel prejudice against the reclamation of castings by welding and to place a useful tool in the hands of the foundry industry. Similarly, work on the welding of non-ferrous metals is being carried out in the laboratories of the British Non-Ferrous Metals Research Association under Dr. E. G. West, who has already published a Paper of a preliminary character.

Just issued, too, is the first report of the British Coal Utilisation Research Association, and some indication of its programme was given by Sir Evan Williams, the President, at the recent annual general meeting. Pulverised-fuel firing, a process very largely practised in the foundry industry, is to receive early and continuous attention. Coincidently with this, researches are to be conducted on producer gas, whilst the domestic grate and cooking stoves are to take a prominent place in the programme. Automatic stoking of large-sized cookers has been an outstanding success and is capable of being developed. It is used in the kitchens of the "Coronation Scot," now being exhibited in the New York World's Fair. As these cookers are so essentially foundry jobs, this work will be followed with interest by the light-castings industry. The staff, directed by Mr. J. G. Bennett, now embraces twenty graduates and thirty-eight non-graduates, and as there is an annual income of the order of £28,000, the new Association has already well established itself. We are still somewhat hazy as to the research structure of the coal interests, and it appears to us that there is need for either centralisation or at least a clarification of the situation. Relying on memory only, we can cite the Fuel Research Board; the Northern, the Midland and the Scottish Coke Research bodies; and the Research Department of the Combustion Appliance Makers' Association (Solid Fuel) as undertaking research on questions appertaining to the use of coal and coke. However, those well versed in the subject inform us that there is no overlapping, yet from the outsider's point of view it does create a difficulty as to which organisation he should approach.

The Post-Congress Tour

HOW GLASGOW, EDINBURGH AND NEWCASTLE ENTERTAINED THE OVERSEAS VISITORS

The Scottish section of the Post-Congress Tour was continued on Tuesday, June 27, the day being given over to visits to important foundries in Glasgow and district. In the morning, alternative visits were available to the works of Harland & Wolff, Limited, Babcock & Wilcox, Limited, and G. & J. Weir, Limited. In the afternoon, works rather more distant from Glasgow were inspected, and parties paid visits to the Singer Manufacturing Company, Limited, the Carron Company at Falkirk, and Glenfield & Kennedy, Limited, at Kilmarnock. The ladies enjoyed a drive in the morning along the famous Three Lochs route in company with a number of Scottish ladies.

The whole party was entertained to luncheon by the Scottish Branch of the Institute of British Foundrymen at the conclusion of the morning visits. Mr. Daniel Sharpe (Convener of the Reception Committee) presided, and was supported by Sir Cecil Weir (President of the Glasgow Chamber of Commerce), who welcomed the visitors, and by Mr. W. B. Lake (President of the Institute).

Civic Reception in Glasgow

The climax of the social functions staged in Scotland was the Civic Reception given by the Lord Provost and Corporation of Glasgow in the magnificent City Chambers on Tuesday evening. In addition to the overseas visitors, members of the Corporation, prominent citizens of Glasgow, members of the Scottish Branch of the Institute of British Foundrymen and their ladies were present. The guests were received by the Lord Provost (Mr. P. J. Dollan) and Mrs. Dollan, and Sir James Lithgow (President of the Reception Committee), and the pipe band of the City Police in full Highland dress paraded in front of the City Chambers during the arrival of the guests. After the reception the Lord Provost's party and officials of the Institute were played to the platform by two pipers.

The LORD PROVOST, in welcoming the guests, spoke of the value of international gatherings in helping the people of other nations to know each other better and so break down mutual distrust and suspicion.

The welcome was continued by SIR JAMES LITHGOW, and responded to by MR. G. R. AMUNDSEN, of Norway, who remarked that a thousand years ago his ancestors came to Scotland as robbers, but now he and his compatriots came as friends.

The LORD PROVOST remarked that Mr. W. B. Lake (President of the Institute) would have to return home the following morning, and, at his invitation, MR. LAKE said goodbye to the overseas guests, and also tendered the thanks of the Institute to the Lord Provost and Corporation of Glasgow and to the Scottish Branch of the Institute.

During the dancing which followed, many Scottish foundrymen and their ladies showed their ability in dancing the Scottish reel, to the intense delight of their guests from other lands. St. George's Square, in front of the City Chambers, was illuminated by four thousand coloured lights, this display and also the presence of the band of pipers being innovations at Civic Receptions, which were much appreciated by citizens and by visitors.

Sightseeing in Edinburgh

On Wednesday the whole of the tourists and a number of Scottish foundrymen and their ladies left for Edinburgh. Mr. Lake was present at the station to bid farewell to the members of the party before he returned south. On arrival in Edinburgh, a number of members of the Institute resident in that city welcomed the visitors, and the remainder of the morning was spent in a drive to the Forth Bridge. On returning to the city, luncheon was given at the invitation of the Scottish Branch of the Institute, Mr. A. D. McKenzie, O.B.E., of Edinburgh, presiding.

In the afternoon the visitors were shown some of the glories of the Scottish capital. The tour of the city commenced with a drive along Princess Street and a visit to Holyrood Palace. The drive then continued along the "historic mile" past the houses of many famous in Scottish history to Edinburgh Castle, where a visit was paid to the Shrine, the War Memorial of which Scotland is so justly proud. An inspection of the Scottish regalia and visits to other parts of the Castle concluded a delightful afternoon.

Farewell to Scotland

Three fascinating days in Scotland concluded with a dinner in the Caledonian Hotel given on Wednesday evening by the Scottish Branch of the Institute. Mr. A. D. McKenzie again occupied the chair, and the gathering included many Scottish foundrymen and their ladies.

The toast of the Institute of British Foundrymen was proposed by MR. W. ROTMANN, of Germany, who spoke of the progress which the Institute had made in recent years.

MR. T. MAKEMSON (Secretary of the Institute) responded, and paid a tribute to the founders of the Institute and to those who had carried it through its early years and so laid the foundation of that progress. He also pointed out that the International Congresses were made possible by the close co-operation which existed between similar associations in other countries and by the friendships existing between the individual members of those bodies.

The toast of the "Overseas Guests" was proposed by MR. DANIEL SHARPE (Convener of the Scottish Reception Committee), and responded to by MR. PIERRE DENIS, of Belgium. Mr. Denis concluded his remarks with a tribute to the perfect organisation of the arrangements in Scotland, which was made possible by the energy and organising ability of Mr. John Bell. A special toast was then drunk to Mr. Bell, who received an ovation when he rose to reply. MR. BELL remarked that the aim of the Scottish members had been to receive the visitors as overseas guests and to make them overseas friends, and he felt that this ambition had been realised.

The speeches were interspersed with musical items, and a happy farewell to Scotland terminated with Auld Lang Syne, after which the Glasgow members and ladies returned to their own city.

South of the Border Again

The journey from Edinburgh to Newcastle-upon-Tyne was made last Thursday morning. The party was met at Newcastle by Mr. Ellis (Branch-President) and other members of the Newcastle Branch of the Institute, and with typical Tyneside hospitality the proceedings commenced with luncheon given by the Branch. In the afternoon the party visited the Roman Wall and the Roman camp of Chesters near Chollerton.

In the evening a dinner was given by the Newcastle members of the Institute in the Royal Station Hotel, those present including many members of the Branch and members of the North of England Ironfounders' Association and their ladies. MR. ELLIS presided, and proposed the toast of the guests. MR. SISSENER, of Norway, replied on behalf of the visitors, and also proposed the toast of the Newcastle Branch. He expressed the thanks of the visitors to Mr. Ellis and Mr. Lashly (respectively President and Secretary of the Newcastle Branch) and to the members and ladies of the Branch, and his remarks were supported by MR. T. FUJITA of Japan and MR. HARASOWSKI of Poland. The last speaker concluded his remarks by expressing the thanks of the guests in seven languages, including Japanese, of which language he has an excellent knowledge.

Presentation to Mr. Makemson

MR. R. ERDOS (Secretary of the Hungarian Foundrymen's Association) said that on behalf of the members of the Post-Congress Tour he wished to pay a tribute to Mr. Makemson (Secretary of the Institute of British Foundrymen), and to express to him the very grateful thanks of all the participants in the tour. Mr. Makemson had carried out a vast amount of work previous to the Congress, the correspondence with the overseas delegates alone having been immense. They were most grateful to him for his assistance throughout the Congress and the Tour.

On behalf of the overseas delegates Mr. Erdos then presented to Mr. Makemson a silver cigarette box inscribed with the words:—

> Presented to Mr. T. Makemson by the overseas delegates at the World Foundry Congress as a token of their appreciation and gratitude. June, 1939.

MR. MAKEMSON, in reply, said he was delighted to receive this souvenir of a very happy period. The organisation of the Congress had certainly entailed much work, but it enabled him to renew many old friendships and to make many new friends in many parts of the world, and like Mr. J. Bell of Glasgow he thought that the overseas delegates had become overseas friends. He also took the opportunity of expressing the thanks of the Institute of British Foundrymen to all the Branches of the Institute who had organised the Post-Congress Tour. He thanked them for their hospitality and for their generosity, and he thanked the many firms who had permitted parties of visitors to inspect their works.

The Polish delegates then toasted Mr. Makemson with a well-known Polish song familiar to those who participated in the International Foundry Congress in Warsaw. Later in the evening Mr. Harasowski delighted the company by a pianoforte recital of works by Chopin.

How the Last Day Was Spent

The last day of the Post-Congress Tour was Friday, June 30, and the gentlemen (and one lady) visited the works of C. A. Parsons & Company, Limited, whilst the remaining ladies, together with ladies from the Newcastle Branch, were taken by car to Whitley Bay. Lunch was again provided by invitation of the Newcastle Branch, and in the afternoon the whole party (including the whole of the ladies) inspected the works of Sir W. G. Armstrong Whitworth & Company (Ironfounders), Limited, at Gateshead-on-Tyne. The party was received by Major Bird (managing director) and Mr. W. Scott (general manager), and thanks on behalf of the overseas visitors were given by MR. LAURANT of France.

The Norwegian members of the Post-Congress Tour remained at Newcastle, from which port they sailed last Saturday. The remaining members of the party left Newcastle for London in the "Coronation" train on Friday evening, and from London they dispersed to their homes.

The Post-Congress Tour was most successful in every respect. The visitors were given every opportunity to see many representative British foundries, in spite of the very difficult conditions prevailing at the present time. They were received with bountiful hospitality by the various Branches of the Institute, and many thanks are due to those Branches for the immense amount of work in planning their respective arrangements.

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New Laboratories for Non-Ferrous Metals Research

ADDITIONAL B.N.F.M.R.A. ACCOMMODATION OPENED BY RT. HON. OLIVER STANLEY

The new laboratories of the British Non-Ferrous Metals Research Association, which were officially opened last Thursday by the Rt. Hon. Oliver Stanley (President of the Board of Trade), are immediately adjacent to the original laboratories in Euston Street, London, N.W.1, and cover a site some 50 ft. by 90 ft. They consist of semi-basement, ground, first and second floors, the main stair being carried up to provide access to the flat roof.

On the lowest floor, the whole of the available site has been utilised, but on the upper floors, in order to give adequate light and air to both new and old buildings, the new building has been planned 32 ft. wide, leaving a space 20 ft. in width between the two buildings, bridged at one end by an external intercommunicating stair.

VIEW IN THE MELTING SHOP OF THE NEW B.N.F.M.R.A. LABORATORIES, SHOWING THE FURNACE PIT AT THE LEFT AND ELECTRIC ANNEALING FURNACE AT THE FAR END.

The new structure is steel-framed with brick panel walls. The suspended floors are of hollow-tile and reinforced-concrete construction, designed to carry 90 lbs. per sq. ft. The flat roof is designed to carry 80 lbs. per sq. ft., and easy access makes it convenient for exposure of specimens to atmospheric corrosion. The lowest floor is of concrete 12 in. thick on a good foundation of sandy clay. The windows have steel frames, and doors are generally flush oak-veneered skeleton core type.

The arrangement of service-pipes has been designed with particular regard for economy in space, clean unencumbered ceiling, wall and floor surfaces, and accessibility. These requirements have been met by running a covered main feeder-trench 2 ft. 6 in. deep beneath the semi-basement floor, around and close to the four main walls. From this trench narrow branch-ducts are taken vertically up for the full height of the building within the external walls—two in each window-pier. These vertical ducts, from which the various rooms are fed, have removable wood covers.

Alternating-current electric lighting and power supplies, under control of a 500-amp. triple pole and neutral oil circuit-breaker and switchgear (situated under the entrance hall), consist of 400 volts 3 phase 50 cycles for power and for the large electric furnaces, and 230 volts single phase 50 cycles for small power, lighting, and heat. The situation of distribution boxes and fuse-boards in the basement at the foot of the rising-ducts is such that future connections or alterations can be made with little disturbance. D.C. supplies to the Physics Laboratory at 220 volts, and to the Mechanical Testing Laboratory at 440 volts, are provided from an 11-kw. hot-cathode-type rectifier.

Melting Shop

The single-storey shop at semi-basement level in the 20-ft.-wide well between the two buildings has facilities for melting, casting, and moulding work. The main melting furnaces are sunk in a pit running along the north side of the shop, the tops of the furnaces being at floor level; space is available in this pit for further installations. Above the centre of the pit is an overhead runway with suitable tackle for lifting crucibles from the furnaces.

At the west end of the melting shop is a small high-frequency melting furnace unit, and at the east end an electric annealing furnace having a hearth capacity of 32 in. by 20 in. Close to this the stocks of metals are kept in heavy racks.

Along the south side of the melting shop is a work-bench, one section of which serves for sand control by B.C.I.R.A. apparatus, whilst another section is a moulding-bench. Moulding sand, coke, and metal moulds are stored beneath, leaving a clear working space 11 ft. wide and 35 ft. long between the furnace-pit and the bench.

Provision is made in this shop for the installation of a small drop-hammer for forging tests.

The main furnaces in the melting shop are as follow—:

(1) Natural-draught 100-lb. (copper) Morgan coke-fired crucible furnace.

(2) A 27-k.v.a. Electric Furnace Company 120-lb. (copper) resistance furnace using non-metallic resistor rods (silit). This furnace is now operated from the a.c. supply through a Scott-connected 3/2-phase transformer, the input to which is 400 volts 50 cycles. Secondary voltage regulation is provided by off-load tappings giving five voltages from 65.1 to 135.2. The sixteen resistor rods are connected on eight different circuits, each carrying two rods in parallel. A Sunvic bimetallic strip thermostat which can be set at a predetermined point maintains a constant energy input by cutting the transformer in and out.

(3) A 100-lb. (copper) gas-fired crucible furnace. Air is supplied at a pressure of 20 in. of water by a two-stage fan and an automatic mixing regulator for the gas and air ensures efficient working over a wide range of speeds of melting.

(4) A 35-k.v.a. Electric Furnace Company high-frequency furnace. This is of the spark-gap type, and three separate furnaces are provided with maximum melting capacities of 22 lbs., 11 lbs., and ½ lb. copper. A fourth furnace-coil is built into a small equipment constructed in the Association's workshops for melting charges up to 2 lbs. copper *in vacuo* or in controlled atmospheres. The high-frequency generator is connected to the main a.c. supply through a trimono transformer, enabling the single-phase converter load to be connected to the 3-phase 4-wire system of the a.c. supply with a partial balance in the ratio of 1 : 2 : 1.

(5) A 21-k.v.a. Birlec electric resistance annealing furnace, with a hearth capacity of 32 in. by 20 in. This furnace, which is fitted with Cambridge thermostatic temperature control, is capable of maintaining a constant temperature up to 1,000 deg., and is connected to the main a.c. supply through a step-down transformer with an output of 146 volts 3 phase 50 cycles.

In addition to these larger furnaces, a number of small gas-injector and wire-wound electric furnaces are provided for small-scale working.

Galvanising and Welding Shop

A room in the semi-basement of the old building, originally a melting shop, is now used for galvanising and welding. This shop, which is 28 ft. long by 12 ft. wide, with brick walls and a concrete floor, is equipped with a fume-extraction system capable of withdrawing a volume of air per minute equal to the full capacity of the room. The electrically heated experimental galvanising pot, 3¾ in. by 10 in. by 13 in. deep internally, has a capacity of just over 100 lbs. of zinc. An overhead runway with a pulley block enables the full pot to be lifted from the furnace at the end of a run for pouring out the metal.

Mechanical Testing Laboratory

This laboratory occupies the whole of the working space (2,800 sq. ft.) in the semi-basement of the new building, one end being divided off to form a constant-temperature room. This room has a floor area of 480 sq. ft., and is maintained at 68 deg. Fah. with a control of temperature to within ± ½ deg. Fah. The automatic temperature control operates by circulation of air at a constant temperature. The air is propelled by a fan through a trunk along the length of the room at ceiling height. The uniformity of temperature attained is such that no two points in the room differ in temperature by more than 1 deg. Fah. The fan draws the air through a box in which are placed four electric heaters and a cooling element (supplied by a 3 h.p. refrigerator). The return air is drawn from near floor level, and in the return trunking it is deflected so as to pass intimately in contact with five thermostats, four of these controlling the heating elements and one controlling the cooling element. Air loss is made up and ven-

tilation provided by drawing about 20 per cent. of the circulating air from outside.

The mechanical testing equipment includes the following:—

Tensile Tests.—(*a*) Amsler 20-ton hydraulic universal testing machine, with seven ranges, from 20 to 0.2 tons; (*b*) Avery single-lever machine having a split counterpoise providing two ranges, 5 tons and 1 ton, and fitted with a variable-speed electric drive; (*c*) a small Avery lever machine, which, originally a wire-tester with a capacity of 500 lbs., has been modified to carry out tests at high or low temperatures on some of the softer materials, such as lead and lead alloys.

Hardness Tests.—Standard Vickers diamond hardness tester.

Impact Tests.—Standard Izod impact-testing machine, which is also adapted for impact tests at high temperatures on specimens supported at both ends.

Fatigue Tests.—(*a*) Wöhler-type machine designed and constructed in the Association's laboratories for use either with single-point or two-point loading, and having a speed of 3,000 r.p.m.; (*b*) a standard Haigh-Robertson wire fatigue-testing machine with speed variation up to 15,000 r.p.m.; (*c*) a reverse bending machine (designed and constructed in the Association's laboratories), which can be used for testing sheet or pipe, either as simple cantilevers or subjected to uniform bending moment over a portion of the length. This machine, which is of the specific strain type, operates at a speed of 1,450 r.p.m.

Creep Tests.—A quantity of creep-testing equipment is in use, both in the main laboratory and in the Constant-Temperature Room.

Machine Shop

In the increased space available in the semi-basement of the old building, the machine tools have been rearranged for individual drive by 3-phase a.c. motors. A welding and brazing hearth and a small forge have been provided. The equipment of the machine shop includes a number of lathes, drilling, milling and shaping machines, and the usual equipment of a small machine shop.

Physics Laboratory

The equipment in this room, which provides about 900 sq. ft. floor area, includes three Hilger spectrographs and a non-recording microphotometer. The smallest spectrograph serves for routine analysis of lead, the medium-size instrument for general work, and the large automatic Littrow spectrograph is used for the analysis of metals and alloys having complex spectra. Both d.c. arc and a.c. spark equipment are in use, the type of excitation used depending on the nature of the work. The microphotometer, giving a quantitative measure (independent of personal judgment) of the intensity of particular lines in the spectra, markedly increases the accuracy of spectrographic analysis.

An interesting piece of apparatus which has been designed and constructed in the Association's laboratories is used for absolute determinations of thermal conductivity of metals and alloys by the longitudinal-flow method. A constant-head water supply is available, together with a transformer for the heating-coils which provides on the secondary circuit currents up to 5 amps. at 220, 140, 40, 30, and 20 volts. Measurements of the gradient and calorimeter temperatures are made by means of base-metal thermocouples used with a Tinsley potentiometer.

In this department is a bullion balance which has been adapted for the determination of specific gravities of large castings, etc. This has a capacity of from 2 to 20 kilograms and an accuracy of 1 part in 100,000. In connection with one of the Association's researches, an apparatus has been designed and constructed for the quantitative measurement of specular and diffuse reflectivity.

Metallography

Two rooms are available for micro-examination and metallographic preparation, respectively. A third small work-room is used for the rough cutting and filing of specimens for the Metallography and Physics Laboratory, both of which are served by an adjacent dark-room.

The preparation room has standard equipment for the polishing and etching of micro-specimens. The microscope room contains two Watson bench metallurgical microscopes and a low-power Watson stereoscopic binocular microscope used for the study of coarse structures, fractures, and other specimens where great depth of focus is desirable. Photographic work is carried out on a large Vickers projection microscope with which magnifications from 3 to 2,500 diameters can be obtained. It is equipped for dark-field illumination and for polarised light. The compactness and rigidity of this instrument render it less susceptible to vibration.

Pyrometry and Heat-Treatment

In addition to the facilities provided in the melting shop for the heat-treatment of larger specimens, a special laboratory is equipped for the heat-treatment of smaller specimens and for the standardisation of thermocouples by means of a standard Tinsley thermo-electric potentiometer.

The furnaces for general use include a resistance furnace with non-metallic resistance-rods for high temperatures, a thermostatically controlled wire-wound furnace, and two thermostatically controlled electric ovens for temperatures up to 350 deg. C. and 150 deg. C., respectively. A considerable number of small furnaces are in use for experimental work on oxidation and scaling tests in special atmospheres. A Cambridge thread-recording millivoltmeter is in use for temperature recording. Several other Cambridge thread recorders and a second potentiometer (Cambridge) are installed in different laboratories (*e.g.*, mechanical testing and corrosion). This pyrometric equipment, and also the numerous precious and base-metal thermocouples, indicators, and millivoltmeters, in use in the melting shop and other departments are issued from the pyrometry laboratory as required.

Chemistry Laboratories

These laboratories are devoted to the analytical work required in connection with the Association's research and development work and to the working out of special methods of analysis. They comprise a main laboratory with standard and special equipment carefully designed for the purposes in view and four adjacent smaller rooms.

The main laboratory is fitted with a fume cupboard containing electric and gas-heated hot plates, and with central and side work-benches. The central benches are supplied with high pressure water for filter pumps, and are equipped with everything necessary for vacuum filtrations. The side benches are largely devoted to titration work. The smaller rooms consist of a balance room; a room for electrolytic and colorimetric estimations; a special laboratory for operations requiring comparative freedom from acid and ammoniacal fumes, and a room for carrying out operations involving the use of sulphuretted hydrogen and other noxious gases.

Corrosion

A main laboratory of about 800 sq. ft. floor area and a smaller laboratory for special operations are situated on the top floor of the old building. Both are provided with the usual services, but fixtures have been kept to a minimum, cupboard and bench accommodation being provided by movable teak-topped units, so that rearrangement of equipment to suit particular work may be carried out easily.

The main laboratory contains a jet-test apparatus for investigation of the resistance of condenser tube materials to attack by rapidly moving aerated sea-water; a special still for producing particularly pure distilled water (saline content less than $\frac{N}{100,000}$) required for corrosion experiments; two glass degreasing units designed on the Soxhlet principle; glass circulators for studying the resistance of galvanised hot-water tanks to corrosion, and an electrolytic stripping apparatus (Britton's test) for measuring the weight, thickness, and structure of zinc coatings on wire and sheet.

The small laboratory is thoroughly equipped for carrying out chemical, microchemical, and micro-examination of specimens and corrosion products.

Bacteriological investigations in connection with the Association's corrosion researches are carried out by a member of the Association's staff working in the Bacteriological Laboratories of the Imperial College of Science and Technology, South Kensington. Atmospheric exposure corrosion tests are carried out on the roof of both the old and new buildings.

General Laboratory

On the top floor of the old building is a General Laboratory about 22 ft. by 15 ft. for light work not specially provided for elsewhere, such as glass-blowing and the construction of apparatus. To some extent this can be regarded as a reserve laboratory which may be adapted either temporarily or permanently for other requirements.

Library

The library, 34 ft. long by 30 ft. wide, occupies the full width of the new building, each side of a central corridor being divided into three bays by book-stacks built up to the ceiling. The six bays thus produced, lined with shelving or cupboards on two sides, provide ample space for expansion for some years. The library contains some 4,000 books and bound volumes and some 20,000 pamphlets and reprints. Name and subject catalogues are provided in a card index containing some 50,000 cards.

Mr. Oliver Stanley on the Growth of Co-operative Research

The official opening of the laboratories was preceded by the 19th annual general meeting of the Association, and a luncheon held at the Savoy Hotel. In the absence of the Chairman (Lieut.-Col. J. H. M. Greenly, C.B.E.) the Vice-Chairman, Dr. H. W. Brownsdon, presided. Mr. Oliver Stanley was the principal guest.

Proposing the toast of the Association, MR. STANLEY caused a good deal of amusement at the outset by declaring that his normal recipe for a speech was a humorous beginning, which he got from the smoking room of the House of Commons; the body of the speech, obtained from his permanent officials, and a peroration which he tried to get from a recent speech by one of his more eloquent colleagues. That day, owing to pressure of work and an unwonted silence on the part of his colleagues, he had only one of these ingredients—the body of the speech—and even that he had not yet had time to read!

In more serious vein, Mr. Stanley said the general question of research was perhaps the most vital that British industry had to solve. A real development of research was essential. Industry was entitled to ask the Government for help when it was in trouble because of something that other Governments had done, but equally it must be sure that everything that lay in its power had been done. One of the most interesting phenomena in British industrial development had been the growth—often too slowly—of co-operative research, such as was exemplified by their association. On a long view more was to be gained by the exchange of information than by secrecy.

He would like to pay tribute to the whole-hearted co-operation which he had received from their industry and to their response to the demands of the Services. They had been called on to meet difficult problems of supply and manufacture.

Position of the Development of Centrifugal Casting in Germany*

By W. A. GEISLER†

Historical

In Germany, centrifugal casting is, as elsewhere, still a recent art which only reached its present state of development after the Great War. No other branch of foundry practice, not even if moulding machines are included, has undergone in the last 20 years such an intensive and exhaustive treatment as centrifugal casting, which, unlike the work on the improvement of steel and cast iron—a province reserved rather for the scientists—has been primarily a matter for the practical man. The first experiments on centrifugal casting which were made in Germany date back to the middle of the last century, although not so far back as the experiments of the Englishmen, A. C. Eckhardt (1809) and A. Shanks (1849).

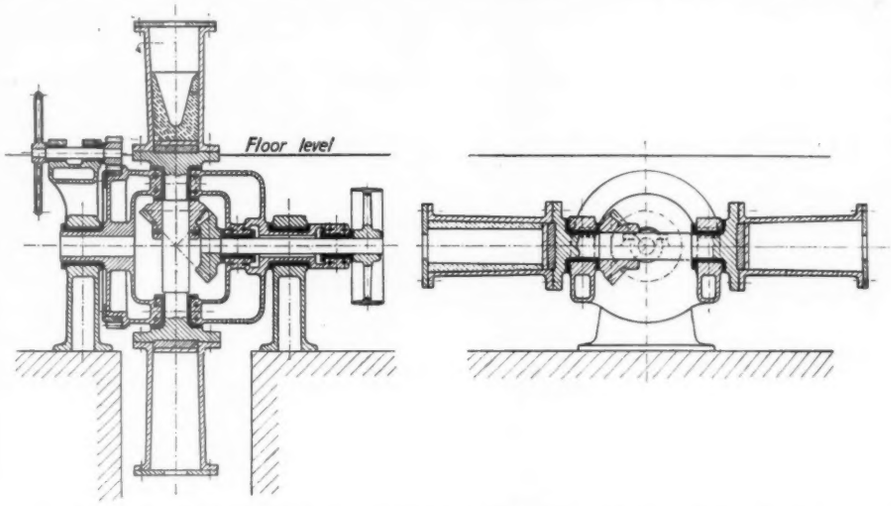


FIG. 1A.—CENTRIFUGAL CASTING PROCESS OF WALZ. GERMAN PATENT 72,478.

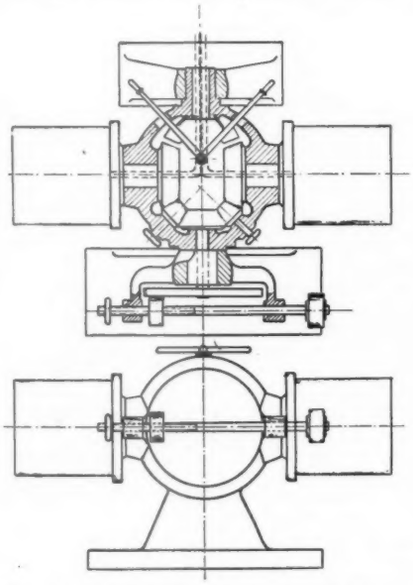


FIG. 1B.—CENTRIFUGAL CASTING MACHINE. GERMAN PATENT 589,350.

Up to the year 1894, there were nine German patents relating to centrifugal casting, but these are not all of German origin. A. C. Eckhardt's British patent of 1809 included all possible constructions regarding the spindle arrangement, and all the subsequent patents relate merely to constructional details or special purposes. A consideration of these early German patents shows that development often goes in circles with frequent repetition. Thus, in 1899,[1] G. Höper took out a patent for a process of centrifugal casting for making slabs or billets to be worked up into wire or sheet. From time to time, this process is to be found again in later patents, but with slight modifications. To-day, the process is again being successfully applied to the manufacture of bronze wire. The process of G. Walz[2] of 1893 has also been repeated. In this process (Figs 1A and 1B), the tubular body is formed by first introducing the molten metal into the vertical or inclined mould, which is set in rotation before the metal is poured, so that a funnel-shaped depression is formed on the surface of the metal. The mould is then slowly brought into a horizontal position, the funnel-shaped depression extending deeper into the ingot until a tube or pipe has been formed, the wall thickness of which becomes more uniform with increasing horizontal position of the mould, until finally, when the position is quite horizontal, a perfectly cylindrical cavity is produced.

A process of the Vereinigte Stahlwerke A.-G., Düsseldorf,[3] is based on this idea, for in this process, also, preliminary centrifuging is effected with the mould vertical, final centrifuging being effected with the mould horizontal.

The machine patented by Hundt & Weber[4] for producing tubular bodies by centrifugal casting is also very reminiscent of the centrifugal casting machine patented 40 years previously, except that in the more recent machine, the two moulds can be disconnected independently from the common driving means.

P. Huth,[5] in 1894, was the first to secure a patent for a process of centrifugal casting for producing compound castings. In the inventor's words,[6] the process is intended to provide certain machine parts, such as track wheels, rolls, gear-wheels and hard-nosed shells and so forth, with correspondingly hard and soft parts in one casting operation.

Fig. 2 shows examples of a track wheel and shell. In the case of the track wheel (Fig. 2A), the harder metal forming the circumference is poured in while the mould is being suitably rotated. The softer metal poured in afterwards forms the underneath part of the tyre, the spokes or disc and the hub.

In the case of the shell (Fig. 2B) the harder metal is poured in while the vertical mould is rotating. In this case, a surface having a paraboloid concavity is formed, on which suitable metal for the remainder of the shell is cast.

In a later publication,[7] the inventor shows the intimate union between the two metals, and considers his process to be suitable, *inter alia*, also for the production of crusher rings, armour plating having a hard surface of any desired depth on one side, guide rolls, cutting tools, roll collars and so forth. Now, 45 years after the grant of Huth's patent, this sphere of work is again being given special attention and detailed treatment.

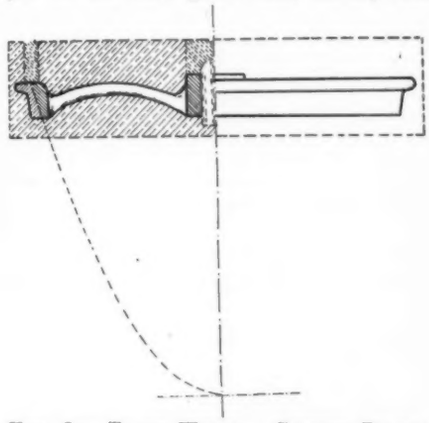


FIG. 2A.—TRACK WHEEL. GERMAN PATENT 78,532.

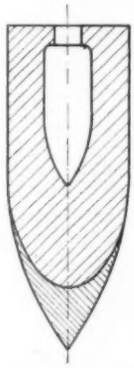


FIG. 2B.—SHELL. GERMAN PATENT 78,532.

(To be continued.)

REFERENCES.

1 German Patent 54056, Georg Höper, Feb. 1, 1890.
2 German Patent 72478, Georg Walz, Jan. 13, 1893.
3 German Patent 531174, Vereinigte Stahlwerke A.-G., Düsseldorf, Oct. 17, 1929.
4 German Patent 589350, Hundt & Weber G.m.b.H., Geisweid, Nov. 26, 1930.
5 German Patent 78532, P. Huth, May 10, 1894.
6 "Stahl und Eisen," 15 (1895), pp. 285–286.
7 "Stahl und Eisen," 17 (1897), pp. 572–573.

* Paper presented to the International Foundry Congress held in London, and organised by the Institute of British Foundrymen.

† Fried. Krupp A.-G., Essen.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

J. Davis & Bailey, Limited, Boxmoor Works, Hemel Hempstead, Herts.—Capital, £15,000. Ironfounders. Directors: J. and B. Bailey.

Hall Sections, Limited.—Capital, £500. Engineers, iron and brass founders, metal workers, etc. Director: W. J. Hall, 12, Rosebank, Rosebank Way, Acton, London, W.3.

International Foundry Congress

Effect of Melting Conditions on the Properties of Castings

PRACTICAL DATA DISCUSSED AT NON-FERROUS SESSION

Six Papers dealing with non-ferrous foundry subjects were presented for discussion at a Technical Session of the Congress held at the Dorchester Hotel, London, on Wednesday, June 14. Mr. D. H. Wood (Junior Vice-President of the Institute of British Foundrymen) occupied the chair.

"The Effect of Melting Conditions on Light Alloys," by A. J. Murphy, S. A. E. Wells and R. J. M. Payne, and "The Effect of Melting Conditions on Gas Unsoundness in Metals," by G. L. Bailey, were the first two Papers presented, and they were discussed together.

Gas Holes and Mass Effect

MR. J. A. REYNOLDS opened the discussion by referring to de-gasification and modification. He said he had found in the case of small melts of about 25 lbs. in a coke-fired crucible, when a proprietary de-gasser or one of the sodium chloride and sodium fluoride type was used, that when attempting to modify afterwards there were invariably tiny gas holes (not pinholes) left in the thin castings. He wondered whether that was due to the fact that one could not leave small melts such as those of 25 lbs. standing after modification for the same length of time as one could leave a melt of, say, from 100 to 300 lbs.

Reversible Reactions

MR. H. G. WARRINGTON, commenting on Mr. Bailey's apparent view that all the reactions of gases with aluminium alloys were reversible, said there was considerable evidence that that was not so. The obvious example was that of oxygen, which immediately formed Al_2O_3, and that did not appear to be reversible on solidification of the metal. There was further evidence in, for example, the casting of ingots. They were apparently soundly cast, but after being subjected to a certain amount of cold work, such as by rolling, there was evidence of gas, by blisters, in quantities which were not obviously present in the original ingot.

Asking for Mr. Bailey's opinion with regard to inter-dendritic porosity, he said that a good many aluminium alloys were subject to such porosity under certain conditions of casting when the eutectic was not sufficient to fill the spaces between the primary grains on solidification; it was generally assumed that the presence of a little gas in the metal would tend to balance that type of porosity by inhibiting to a certain extent the contraction at the moment of solidification. Were there real grounds for assuming that that was of advantage, or was the complete de-gasification of the metal beneficial in all cases?

Admissible Gas Content

MR. A. J. SHORE, enlarging upon Mr. Warrington's remarks, said that recently at his works some trouble had been experienced with shrinkage in a 12 per cent. modified silicon alloy, and the matter had been discussed with the suppliers. The latter had said that the metal was too free from gas and that they would supply metal which had a slight gas content. That was done, and the shrinkage troubles were overcome.

He asked Mr. Murphy whether a 12 per cent. modified silicon alloy was more active with regard to iron pick-up than, say, a 6 per cent. alloy. Did the silicon in the 12 per cent. alloy attack the iron at a greater rate? At his works some trouble had been experienced due to spoiling the modification and obtaining the large crystals referred to in the Paper by Messrs. Murphy, Wells and Payne. The iron content was certainly rather high—it was, however, less than 1 per cent.—and it was decided to scrap the cast-iron melting pots and to use plumbago pots in consequence. He asked for an opinion as to whether that change-over was the right policy.

Magnesium and Aluminium Practice Compared

MR. G. LUTOSLAWSKI (Warsaw) said it had been the belief that the influence of gas upon magnesium alloys could be neglected; but recent experience had shown that the effect of gas upon magnesium alloys, and especially the effect of hydrogen, seemed to be very important from the point of view of the soundness of the castings made in those alloys. Hydrogen pick-up during the melting of magnesium alloys seemed to be due to the moisture in the charged metal, and in many cases it seemed practicable to dry the metal to be charged, in order to avoid that hydrogen contamination. The problem was not yet quite solved. Not only did the hydrogen give rise to porosity, but one could also observe the growth of the grains in the magnesium castings when hydrogen porosity was present. It might be, as Mr. Murphy had said, that in some aluminium alloys a small gas content was beneficial for refining the grain during solidification; but that did not appear to be the case in the magnesium alloys. Indeed, in the magnesium alloys the position seemed to be just the reverse in that respect, just as in many other respects the behaviour of the magnesium alloys was the reverse of that of the aluminium alloys.

Drawing a parallel between the behaviour of magnesium alloys and ferrous alloys such as grey iron and some kinds of steel, Mr. Lutoslawski said that in melting steel which contained chromium, for instance, if hydrogen were present it generated a very coarse structure and sometimes gave rise to considerable trouble. The effect of that phenomenon appeared to be very similar in magnesium, though perhaps for different reasons.

He drew another parallel between magnesium and ferrous alloys in regard to the effect of superheating. By superheating the magnesium alloys one obtained a fine-grained structure, just as one obtained a fine-grained structure in grey iron by superheating. Again the reasons might be different in the two cases, but the effect was similar.

Magnesium Content and Hardness

MR. A. LOGAN, congratulating the authors, said that the two Papers formed a very admirable groundwork for anyone entering the field of light alloys. As the industry progressed, technical knowledge grew; those who had entered the field of aluminium alloys years ago would have been in a very fortunate position had the information obtainable from such Papers as these been available in the early days.

The Paper by Messrs. Murphy, Wells and Payne explained quite a number of phenomena which only intelligent pre-knowledge could either cater for adequately or circumvent. Various pitfalls were mentioned, such as gas absorption, and contamination in aluminium and in magnesium alloys, as well as change of composition in alloys containing small amounts of magnesium. The latter effect could be very troublesome, especially in alloys where only, say, 0.3 per cent. of magnesium was the maximum amount present. The effect was a considerable reduction of hardness if the magnesium content fell. In an alloy containing, say, 10 per cent. of copper, 1 per cent. of iron and 0.3 per cent. of magnesium, a reduction of 0.1 per cent. in the magnesium content was sufficient to reduce the Brinell hardness from 150 to 120 in the heat-treated condition. That rendered the alloy quite unsuitable for the purpose for which it was required. The same effect occurred in alloys of higher magnesium content also, and Y-alloy was mentioned in the Paper in that respect. He asked whether the authors had found the same reduction of magnesium content when chlorine fluxes were used.

Another matter to which he referred was the coarsening of the grain when the metal was held for a long time at a temperature below the critical value of about 750 deg. C. Grain coarsening in some cases seemed to be due to a time-temperature reaction. As to the suggestion that grain-coarsened material produced by heating at 750 deg. C. could be restored to the fine-grained condition by casting in chills and re-melting, he said that that might be accepted with a little reserve, for he could provide examples of material which had not reacted in that way, the coarse grain having persisted even after re-melting. The undesirability of large grain size was well known to aluminium founders, and was rightly stressed in the Paper.

A very remarkable feature mentioned in the Paper was the difference in the feeding properties as between coarse-grained and fine-grained material. The very much improved "feeding" of fine-grained material was quite extraordinary, and it had to be experienced in order to be appreciated fully, but it was a valuable foundry asset.

Commenting on the authors' reference to niobium and titanium as grain-refining elements, he said that possibly they had not covered the whole ground there. He did not suggest that they were not aware of other such elements; but he personally had obtained remarkable results with boron, which had been known for years and was a very powerful grain-refiner.

Finally, he paid a tribute to Mr. Bailey for the valuable nature of his Paper.

Protection for Cast-Iron Sheaths

MR. E. N. NOBLE, dealing with a reference to a protective material for cast-iron pots used for melting magnesium alloys, mentioned his experience on cast-iron pyrometer tubes, when a piece of tube had melted immediately at the surface of the metal and had dropped in. He asked, therefore, whether one could use cast iron for that purpose with a protective material, and, if so, whether Mr. Bailey could recommend such a material.

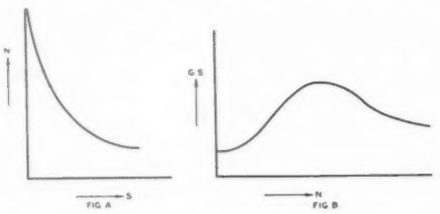
Grain Size and Nuclei

MR. G. L. BAILEY, discussing the Paper by Messrs. Murphy, Wells and Payne, agreed that the factors influencing grain size should be studied more thoroughly, as too little knowledge was available about the control of grain size and the factors influencing it, although we knew that such things as titanium and niobium would solve the practical problem in aluminium alloys.

Discussing the theoretical side of the question, he said that, so far as we knew, the grain size of the metal depended on the number of nuclei in the melt at the moment solidification commenced. Those nuclei might be of two types, first the type to which Mr. Murphy and his colleagues had referred, *i.e.*, the nuclei which existed in the fluid metal, and secondly, the type of nuclei formed spontaneously at the moment of crystallisation. It was very difficult to determine the extent to which one or the other type was responsible for the ultimate grain size of a particular casting. The nuclei formed spontaneously on solidification were formed in greater numbers the greater the degree of super-cooling. On the other hand, the greater the number of nuclei which existed in the mould to start with—by which he meant the type of nuclei which might or might not be a slag cloud or something of that sort, and which acted as centres of crystallisation—the less the degree of super-

cooling. The curve in Fig. A illustrated roughly the effect of the number of nuclei present in the melt (N) on the degree of super-cooling obtained (S).

In the absence of nuclei initially in the mould there might be severe super-cooling, whereas in the presence of large numbers of nuclei, super-cooling might be avoided altogether. Severe super-cooling gave more spontaneously formed nuclei at the moment of solidification. Therefore, it seemed to him that if there were no nuclei of the type mentioned by Mr. Murphy and his colleagues, *i.e.*, those which existed initially in the fluid metal, there might be severe super-cooling and a very fine grain, and with a large number of spontaneously formed nuclei present, one might also get a very fine grain. But between the two there was a moderate degree of super-cooling and a moderate number of nuclei, and one might obtain a coarser grain. This was roughly illustrated in Fig. B, where grain



size (GS) is plotted against the number of nuclei present in the melt. The coarsening of grain could therefore be accounted for by two exactly opposite explanations, *i.e.*, because there were fewer nuclei and more super-cooling or, alternatively, more nuclei and no super-cooling. He was not convinced that that theory held universally, or that it held at all, and only mentioned it to support Mr. Murphy's contention that metallurgists ought to find out more of what was happening on solidification if they were to be able to control grain size in the way they would like.

Deoxidising with Cadmium

MR. J. A. REYNOLDS, dealing with the references in Mr. Bailey's Paper to the relative advantages or disadvantages of cadmium as compared with phosphor-copper for the deoxidation of high-conductivity copper sand castings, said there were certain compounds, such as beryllium-cobalt, which were subject to precipitation hardening on heat-treatment. Cadmium offered a much cheaper method of obtaining the same results, but in applying it to sand castings a mass of confused results had been obtained so far. For chill castings, cadmium-copper alloys were used quite regularly, but for sand castings he had not found much to help him so far.

Mr. Wells' Reply

MR. S. A. E. WELLS, replying to the question of Mr. Shore concerning the relationship of silicon content to iron pick-up when melting alloys in iron pots, expressed the view that Mr. Shore had adopted the right attitude in changing over to plumbago pots as a precaution. The authors had found, however, that the whitening silicate dressings they had recommended were quite effective if properly applied and maintained. With regard to the effect of the percentage of silicon on the pick-up of iron, he believed it was right to say that the higher the silicon content the greater the action upon the iron became.

The authors were unable to say much about Mr. Logan's point in connection with the coarsening of grain of the molten metal resulting from holding the metal for a long time at a temperature below the critical value of about 750 deg.; they had not examined that aspect yet. The authors had always found the correction of the grain size by re-melting at a temperature not exceeding that critical value to be satisfactory. But inasmuch as the question of nuclei mentioned by Mr. Bailey was shown to be so involved, there might be some explanation of irregularity of behaviour about which, at the moment, the authors did not know.

The authors had not made an exhaustive examination of all possible grain refiners, but they did examine a dozen or more. Boron was not examined, because they were already aware of its effects.

Mr. Payne's Reply

MR. R. J. M. PAYNE, replying to Mr. Lutoslawski's comments on the solution of hydrogen in magnesium, said that in the experience of the authors that was not a major problem. Where they had had trouble due to coarse grain, the material had always responded to super-heating treatment, and they had never been able to attribute the trouble to hydrogen in the metal. Of course, there was a good chance of the hydrogen dissolving in the magnesium, because the fluxes used contained water of crystallisation. However, he repeated that gas, even if present in magnesium alloys, caused no difficulties.

Mr. Bailey's Reply

MR. G. L. BAILEY, replying to the discussion on his Paper, agreed fully with Mr. Warrington that not all gas reactions were reversible, and he corrected a quite erroneous impression which apparently he had given in that respect. What he had intended to indicate, he said, was that simple gas solubility relationships—for instance, the solution of hydrogen in a metal—were reversible. Gas reactions, however, involving oxides, might or might not be reversible, depending upon the solubility of the oxide in question. In the case of aluminium in particular, where hydrogen was picked up by reaction with water vapour, the oxygen was not taken up at all; that was clearly a case of a non-reversible reaction.

Coming to the question raised by Mr. Warrington and Mr. Shore as to the effect of gas content upon interdendritic porosity and shrinkage, he said there was no doubt that in some types of alloy, especially for certain purposes, such as die-casting, a little gas had advantages. It scattered the shrinkage. The distinction between gas and shrinkage unsoundness was in many cases almost impossible, but it was an advantage in some cases to have the unsoundness scattered throughout the section rather than concentrated in one place. The total amount of unsoundness present, if there were gas, was certainly not less than if there were no gas; it might be more.

The modified silicon alloys were liable to scattered unsoundness which could be produced by gas, but he was becoming more and more convinced that it could be produced also in the absence of gas; with the most thorough degasification and subsequent modification one was still liable to produce scattered unsoundness, due to a scattering of the shrinkage unsoundness by some factor we did not yet understand fully.

With regard to Mr. Reynolds' reference to the relative merits of deoxidisers for copper alloys, he would say from a limited experience that cadmium was not an adequate deoxidiser for copper, and that in making cadmium-copper some other deoxidant must be employed, otherwise there would be unsoundness due to hydrogen-oxygen reactions.

MELTING OF LIGHT ALLOYS

The next two Papers presented and discussed were "Light-Alloy Melting Practice," by W. C. Devereux, and "The Influence of Repeated Remelting on the Properties of Light Alloys," by Dr. J. Koritta and Ing. M. Hajek.

In the absence of the authors of the latter Paper, it was presented on their behalf by Prof. Pisek.

MR. W. WEST commented that Mr. Devereux's Paper did not leave much opportunity for discussion, because the points were put forward so excellently. All in the aluminium foundry trade would like to use the low-frequency furnace; but they were not all concerned with the production of the most expensive form of casting for aero work, and in consequence had to be satisfied with the next best melting unit, the cost of which was much lower.

He had tried to correlate the cost figures in the Paper with those obtained with oil-fired furnaces, but due to the variation of local conditions, one could hardly make a close comparison.

In asking what chances there were of getting low-frequency furnaces into this country, he said Mr. Devereux had already stated that not many had yet been installed; and he commented jocularly that it might have been better to have presented the Paper to a meeting of company directors, so that they might understand exactly where the jumping-off point was situated.

Confirming the point made in the Paper with regard to the bowl type of furnace and the insertion of sulphur dioxide, he said that as the result of experience at his works in magnesium casting, sulphur dioxide had been introduced into aluminium die-casting also. Where the design was rather intricate and the flow of the metal tended to turbulence in the mould, they had fitted up the dies with small bottles of sulphur dioxide, and tried to keep a closed top. As a consequence, they were getting much better results.

Correct Mixing?

MR. G. L. BAILEY, referring to the influence of repeated melting on the properties of light alloys, asked for enlightenment as to the significance of Fig. 1 in the Paper by Dr. Hajek and Mr. Koritta. It appeared that in melting and re-melting metal, one must not mix such alloys as aluminium-copper-magnesium with aluminium-copper, or that one could melt them only in limited proportions. If that were the correct understanding, he could not follow it, because one was not introducing foreign elements or any incongruous materials by putting aluminium-copper into aluminium-copper-magnesium.

Fluxes for Reducing Alumina

MR. A. LOGAN, referring to the Paper by Dr. Hajek and Mr. Koritta, pointed to the statement therein that the fluxes currently used did not have a decisive influence on the reduction of the aluminium oxide. As far as the statement in the Paper went, it was correct, he said; but it did not follow that one could not lower the aluminium oxide content in a charge of molten metal by the use of fluxes. It was quite possible, and he believed it was current practice, to reduce the aluminium oxide content of molten metal by using suitable fluxes. The oxide was not actually chemically reduced, but could be eliminated or partially eliminated by mechanical action; and the reduction of the aluminium oxide content was a factor of very great practical importance in aluminium founding. He would welcome the experience of others concerning the amount of aluminium oxide permissible, for he had fairly definite ideas about it. He had indications that the presence of aluminium oxide beyond a certain limit was in itself sufficient to cause considerable trouble.

Mr. Devereux's Reply

MR. DEVEREUX replied to the discussion on his Paper. He agreed with Mr. West that it was very difficult to obtain a really good induction furnace, and that the cost was high. In his view, the work which he and his colleagues had done on the furnace proved that it was worth the expense, and during the past four months they had put into construction 15 furnaces themselves, although as yet only five were completed. The cost of the furnace itself was roughly £1,400, and with the complete electrical equipment it cost about £1,700, which compared with about £1,000 for the oil-fired crucible type of furnace of similar output.

He was obtaining really excellent results with the induction furnaces they had tried, their experience covering three furnaces, two years with

one in Switzerland, varying down to about nine months with others; at his company's Redditch works that type of furnace would be used entirely in the one foundry, the other foundry being run with half induction furnaces and half other types. He believed the results obtained with sulphur dioxide with aluminium alloys was due largely to the class of alloy; he imagined there was some advantage in using it with, say, an alloy of high magnesium content.

DIE-CASTING ALUMINIUM- AND ZINC-BASE ALLOYS

The Paper on "Pressure Die-Casting in Aluminium- and Zinc-Base Alloys," by Dr. Arthur Street, was introduced by the author, who suggested that, by referring to the limitations of the process of die-casting, he had at least managed to discuss an aspect which was comparatively rarely considered.

When he had decided to place on record some of the limitations of die-casting, he had approached a number of foundrymen either verbally or by letter to ask their opinion about pressure die-casting. It was a humbling experience to find that in many cases foundrymen just had no reaction at all to the die-casting industry; but it was interesting that the people who had considered the subject did not feel that die-casting was an annoying rival, but was rather what one might call the junior partner of the casting-die-casting axis.

In discussing the solidity or otherwise of die-castings he had embarked upon a subject which could not be dismissed lightly in a few paragraphs, but he had tried to show that the problems connected with unsoundness were rather different from those which the ordinary founder met, and he hoped he had been able to give the opinion that pressure die-castings were capable of being produced free from unsoundness.

He had tried to make it clear in the Paper that pressure die-casting did not consist merely of making an expensive tool and commencing immediately to produce castings at the rate of a few thousand per day; but with increasing experience, production speed rose to an outstanding degree. Recently he had been in the toils of a case where a perfectly innocuous looking die, producing a pair of aluminium alloy pressure die-castings, had been in process of being "run in" and had given trouble for practically three weeks before it would consent to produce satisfactory castings. During that time, between three and four hundred rejects had been produced, and then on one day 20 good castings were produced. That was an extreme case, but it illustrated that the making of pressure die-castings was not the purely mechanical process that many people imagined it to be.

DR. E. M. LIPS (Netherlands) emphasised the value of the Paper by reason of the exact data it contained. He asked for Dr. Street's opinion as to the bending properties of a die-casting; for instance, the possibility of making a turned-in flange as a manner of fastening some part to a zinc die-casting.

Porosity Determination by Weighing

MR. A. J. SHORE said that, having received a *questionnaire* from Dr. Street, he had looked into the question of die-casting at his own works. It was apparent that it was not considered to be a very important rival, or it would have been forcibly brought to his attention before. Although they had been carrying it on for about 15 years, die-casting had not made any deep inroad into the grey-iron business. But it had certainly a very big field, and the company had recently bought new machines which were likely, he felt, to cut in on their grey-iron business to some extent, because as the machines were more efficient and *new*, the designers would take a greater interest in them. They would consider as many components as possible as die-castings in order to keep the machines busy. Recently he had visited the die-casting department and had looked into the business thoroughly, and was surprised to find that porosity did occur occasionally; he was assured that it was practically absent on the automatic machines, but that it did happen occasionally on the hand-operated machines when a man, who was paid piecework rates, tried to operate the machine too quickly. The result was that insufficient time was allowed for the metal to enter. That problem had been solved in a simple way by using a delicate weighing machine; the castings had a standard weight, and because they were dimensionally accurate, the weight was a very good indication of the porosity.

He congratulated Dr. Street on his very direct and courageous way of presenting the Paper.

Chilled Skins on Die-Castings

MR. A. TIPPER, M.Sc.(Eng.), thanked Dr. Street for having put his case rather from the point of view of the foundrymen than the die-caster; this gave the founders the opportunity to state their case initially.

Being interested in the finish obtained on small die-castings which had to be plated, he asked Dr. Street what were the most important factors determining that finish—whether it was merely a question of the surface of the die, or whether the actual operating conditions, such as the temperature, and so on, and the composition of the alloy, had much effect. Recently he had examined the microstructure of a number of plated die-castings and had been quite surprised to find that there was not even microscopic porosity near the surface, within perhaps ten thousandths of an inch of the surface. There appeared to be columnar or chill crystals, although they were by no means regular. He asked whether it was normal in ordinary die-cast alloys to have a depth of something like ten thousandths of an inch of chill crystals at the surface.

Dr. Street's Reply

DR. STREET, dealing with the question by Dr. Lips concerning the bending radius that was possible in die-castings, said that presumably brass was referred to; but very few brass pressure die-castings were made. The usual competitors which the die-casting industry put forward were the zinc-base alloys, and they had not a very large bending radius. However, it depended upon the design. One could be considered fortunate if one could bend a sheet of zinc-base die-casting to 90 deg. The operation of bending a die-casting rarely arose, because by using a die-casting the process of bending could be eliminated. Thus it did not really matter whether a zinc alloy could or could not be bent through a large radius.

Commenting on Mr. Shore's reference to the competition between grey iron castings and die-castings, he compared the price of grey iron castings of about 2½d. per lb. with a zinc-base alloy pressure die-casting at about 6d. to 8d. per lb. Unless the weight of the die-casting could be considerably reduced, or unless the die-casting would eliminate a quantity of machining, it was difficult for the die-casting industry to compete directly with the foundry.

As to porosity, he felt that if in a die-casting there were holes which were capable of being discovered by the operation of weighing, the holes must be rather serious ones. If one produced a die-casting in which there was a hole as big as a pea, one should not merely shrug one's shoulders, but should get really worried about it. One could tolerate, say, an occasional hole perhaps as big as a small pinhead in die-casting. It was sometimes difficult to get die-castings more solid than that, but a large hole should not be tolerated. With regard to porosity being more likely to arise when working at low pressure with a hand-operated machine than when working at high pressure, he said that the high pressure certainly reduced the likelihood of unsoundness.

Replying to the remarks of Mr. Tipper concerning the chill skin of a pressure die-casting, he said that inasmuch as the metal came into such violent contact with a comparatively chilled wall in the mould, it acquired a skin about 15 thousandths of an inch thick, which had an extremely fine grain; underneath that, the alloy was more or less normal. Consequently, in any polishing operation it paid to avoid polishing below the first 15 thousandths of an inch or so of skin; otherwise, one would have a mixture of fine and normal grain.

In regard to plating—he presumed Mr. Tipper was referring to zinc-base alloy die-castings—a number of points were important. Naturally, the castings must be without pinholes, otherwise those pinholes might show up on the plated surface. Then the various operations before plating were important. The polishing must be thorough; but one must not remove the fine-grained skin. There was an art in preparing a zinc-base alloy for plating; it was useless showing it to the mop and then taking it to the plating shop, because in that case a rather draggy surface was the result. Many of the troubles which could not be explained in regard to zinc-base die-castings arose from insufficient cleaning.

A telegram was received from DR. R. IRMANN, author of the Paper on "The Solution Heat-Treatment of Aluminium Casting Alloys," in which he expressed his regret that he was unable to attend the Congress personally. In those circumstances, it was suggested that questions might be transmitted to the Secretary in writing, so that they could be submitted to Dr. Irmann.

Vote of Thanks to Authors

MR. F. HUDSON, proposing a vote of thanks to the authors of the Papers, said it would be agreed that all of them were of exceptional practical value. It was particularly interesting to note that much had been said regarding factors which were of importance in connection with the melting of non-ferrous materials in both the light alloy and copper base groups. Such information was of considerable help to foundrymen.

Messrs. Murphy, Wells and Payne indicated in their Paper the ways and means of controlling grain size in aluminium and magnesium alloys by control of melting conditions and by the addition of small amounts of special alloys. One would like to assure the authors, and incidentally their firm (J. Stone & Company, Limited) that the Congress appreciated in no small measure their contribution to the proceedings.

The effect of melting conditions on gas unsoundness in metals was not an easy subject to expound, and Mr. G. L. Bailey should be commended for having put forward his views in so simple and understandable a way. Remembering the most interesting lecture delivered on the previous day by Prof. Bragg on the subject of "The Atomic Pattern of Metals," one could not help but feel that there were very many matters on which further information was desired, and probably so far as the foundry was concerned increased knowledge of thermal reactions, particularly the effect of gas in molten metals, was urgently required.

One very important point to remember in connection with this subject was that the usual methods employed for determining the amount of gas present did not seem to give anywhere near true results. This was strikingly exemplified two years ago at the Derby Conference of the Institute of British Foundrymen in the French Exchange Paper presented by Prof. Chaudron entitled "The Elimination of Gaseous Impurities in Aluminium." In that Paper Prof. Chaudron outlined a new method for estimating the amount of gas contained in metals, which consisted of bombarding the specimen in a

(*Concluded on page* 10.)

Effect of Melting Conditions on Gas Unsoundness in Metals

By G. L. BAILEY, M.Sc.

(*Concluded from page* 578, *vol.* 60.)

Furnace Atmospheres

Reliable analyses of the composition of the atmosphere in contact with the metal in different types of melting furnaces are not easy to come by. Considerable numbers of analyses of furnace and flue gases are published, but commonly omit water vapour, clearly most important in the present connection. R. J. Anderson and J. H. Capps[11] analysed the gases in contact with aluminium alloys in various types of melting furnaces without including water vapour. The results they give, however, are of interest and their analyses for four types of furnace are reproduced in Table III. The balance was assumed to be nitrogen.

TABLE III.—*Composition of Furnace Gases.* (Anderson and Capps.[11])

Type of furnace.	Composition per cent. by volume.				
	Oxygen.	Carbon dioxide.	Carbon monoxide.	Hydrogen.	Hydrocarbons.
Stationary gas-fired crucible furnace	0.0 to 4.5	6.7 to 10.8	1.9 to 6.3	0.7 to 6.2	0.3 to 5.4
Stationary oil-fired crucible furnace	2.0 to 12.6	6.4 to 14.5	Nil	0.0 to 0.4	0.0 to 0.5
Open-flame oil-fired reverberatory furnace	2.9 to 20.8	0.1 to 12.1	0.0 to 0.7	0.0 to 0.1	0.1 to 0.4
Indirect-arc rocking electric furnace	0.0 to 7.6	0.0 to 8.4	16.0 to 42.8	0.0 to 28.6	0.0 to 3.0

Allen and Hewitt, in the course of Allen's well-known work on unsoundness in copper, carried out for the B.N.F.M.R.A., made a large number of analyses of the composition of the furnace atmosphere in different types of copper-refining furnaces. The results varied widely according to the position and time of withdrawal of the sample, but the variations in composition obtained are shown in Table IV, the balance again being nitrogen.

These analyses include water vapour, which in fuel-fired furnaces generally constitutes the highest proportion of reactive gas. An interesting feature is the very small proportion of free hydrogen or of hydrocarbons found under the conditions of these determinations. Assuming access of the gas to the metal, any considerable amount of free hydrogen is bound to lead to hydrogen solution in almost any metal. From these analyses little hydrogen would be picked up in this way, and it would appear that the most important source of introduction of hydrogen is reaction with water vapour. The discussion of the "solubility" of water vapour in metals in an earlier section was particularly concerned with cases in which both the hydrogen and oxygen were soluble to some extent. Apart from the production of reaction unsoundness under such conditions, water vapour reacts with metals such as aluminium, forming hydrogen which is dissolved in the metal, and aluminium oxide which accumulates on the surface. Hanson and Slater[13] first called attention to the great importance of water vapour as the source of hydrogen dissolved in molten aluminium, this hydrogen alone being the main cause of pinholing. Some of their results on the effect of treating aluminium and aluminium alloys with steam are reproduced in Table V.

The other compound gases which are likely to give trouble are the oxides of carbon and sulphur dioxide. Carbon dioxide at melting temperatures can be regarded as an oxidising gas towards most metals, the first reaction being production of the metallic oxide and carbon monoxide. The rôle played by carbon monoxide itself is somewhat uncertain. There appear to be cases in which carbon monoxide can cause unsoundness by what appears to be a simple solution and consequent evolution on solidification without dissociation forming carbide and oxide. Lepp[13] states that carbon monoxide is soluble in molten copper.

The effect of sulphur dioxide has been much discussed, and definite evidence that this gas causes unsoundness in anything other than pure copper is lacking. There is no doubt that contact with sulphur dioxide is harmful in that it causes absorption of sulphur which may be soluble in the liquid and thus form sulphides which are trapped on solidification. Sulphur dioxide, for instance, is an undesirable constituent in a furnace atmosphere in the melting of nickel and nickel alloys in which excess of sulphide causes embrittlement. In tin bronzes, there is no clear evidence that the oxygen solubility is high enough to cause marked reaction unsoundness with dissolved sulphur, but it does appear that the solubility of sulphur in the molten metal is sufficiently great to cause serious contamination of the solid metal with sulphide particles. These not only act as discontinuities between the metal crystals but also tend to increase shrinkage unsoundness by mechanical obstruction of the feeding of solidification shrinkage through the interdendritic channels.

TABLE IV.—*Composition of Furnace Gases.* (Allen and Hewitt.)

Furnace.	Fuel.	Composition of furnace gases. Per cent.						
		O_2	CO_2	CO	H_2	Hydrocarbons.	SO_2	H_2O
Bailey ..	Electric resistance (carbon granules).	0.0 to 0.4	4.1 to 19.3	0.1 to 41.5	0.0 to 1.4	0.0 to 0.9	—	0.25 to 0.8
Reverberatory.	Coal, forced-draught.	0.0 to 22.4	0.3 to 13.5	0.0 to 7.0	0.0 to 2.2	—	0.0 to 1.7	0.0 to 12.6
,,	Coal, natural-draught.	0.2 to 20.9	1.1 to 16.3	0.0 to 15.3	0.0 to 0.2	—	0.0 to 3.0	0.0 to 20.7
,,	Oil	0.0 to 5.8	8.7 to 12.8	0.0 to 7.2	0.0 to 0.2	—	0.3 to 1.4	7.5 to 16.4
Crucible ..	Oil: outside crucible.	2.9 to 4.4	10.8 to 11.6	0	0	0	0.4 to 2.1	8.0 to 13.5
	Oil: 2 in. above metal surface.	0.2 to 3.9	7.7 to 11.3	0.4 to 4.4	0	0	0.4 to 3.0	11.8 to 12.3

Minimising Gas Unsoundness

This discussion leads to certain suggestions concerning desirable melting practice for the reduction of gas unsoundness to a minimum, which can be summarised as follows:—

(*a*) Ensure the use of clean metal free from gas contamination or corrosion product. Similarly avoid charging into the pot damp fluxes or any materials which, on heating, evolve detrimental gases which are liable to be absorbed by the melt.

(*b*) In general, melting in a slightly oxidising atmosphere is to be recommended. This ensures the absence of free reducing gases in the furnace atmosphere and also reduces the amount of detrimental reducing constituents such as hydrogen in the melt. On the other hand, oxidation must, of course, not be overdone, or the result will be a casting badly contaminated with non-metallic oxide inclusions and high oxidation melting losses. It is suggested, however, that in older practice oxidation melting losses have been given an undue importance, and their elimination by melting under reducing conditions is liable to introduce more serious defects in some materials.

(*c*) As far as possible the water-vapour content of the atmosphere should be kept down to a minimum. For instance, coke should be dry. It must be admitted that it is not possible to eliminate water vapour from the atmosphere of any fuel-fired furnace, as the air used for combustion contains from 1 to 2 per cent. of water vapour, and most fuels used contain hydrocarbons, the combustion of which forms water vapour.

(*d*) The metal should be protected as far as possible from direct contact with the flame or with products of combustion. In crucible melting, porosity of the crucible itself is a factor which should be considered, and a crucible which glazes over on the surface has obvious advantages. An inert slag is frequently desirable to protect the exposed surface of the metal. Glass is very effective in this way, but such slags are in general rather corrosive towards crucibles and furnace linings. Charcoal is very largely used as a cover in melting, its use originating mainly with the object of preventing oxidation losses. From this point of view it is very effective, but the use of charcoal as a cover may have a harmful effect either on account of an increase in the carbon-monoxide content of the atmosphere adjacent to the metal surfaces or because it tends to remove excess oxygen from the furnace gases and thus facilitate hydrogen absorption (or alternatively decrease hydrogen elimination).

(*e*) Rapid melting is important. The longer the metal is exposed to a deleterious atmosphere the more opportunity is provided for absorbing detrimental gases, particularly if the metal is allowed to run down exposed to the furnace atmosphere instead of being charged into a pool of molten metal. Rowe,[14] melting 10 per cent. tin bronze containing 0.3 per cent. phosphorus in a coke-fired pit furnace, found a loss of 4 tons per sq. in. in tensile strength and 10 per cent. in elongation when melting time was extended from 45 to 145 min.

(*f*) Over-heating should be avoided. It is apparent from what has been said earlier about increase in solubility of gases in metals as the temperature is raised that heating to a higher temperature than is necessary in the furnace will encourage excessive gas solution, and it is not

at all certain that subsequent cooling to the correct casting temperature causes this excess gas to be evolved. This would only be expected to be the case if the metal were saturated with gas at the high temperature. What is more likely is that equilibrium is not reached in ordinary practice, and the additional amount of gas dissolved during the over-heating period is still within the equilibrium amount at the casting temperature.

Removal of Gases

There are some cases in which complete avoidance of gas contamination is difficult and costly, and in such cases, as well as with accidentally contaminated melts, the use of a degassing treatment prior to pouring is the best practical course. It is not proposed here to deal in any detail with the many and varied methods which have been proposed for the removal of dissolved gases, but only to call attention to the general principles involved in these methods. The most important of these is based on Sieverts'[11] observation that the solubility of a gas in a molten metal varies with the square root of the pressure of the gas in the atmosphere in contact with the metal. It follows that a decrease in the partial pressure of a particular gas will result in the removal of a corresponding amount of this gas from solution. Thus hydrogen, for instance, in solution in a metal can be removed if the hydrogen and hydrogen-containing gases are removed completely from the atmosphere by displacement with some inert insoluble gas, such as nitrogen. This is the basis of Archbutt's[15] nitrogen-treatment method for degassing aluminium alloys and of a number of similar methods in which the contaminated atmosphere is swept away and replaced by an inert one into which the dissolved gas will diffuse. Where free diffusion is mechanically obstructed by an insoluble oxide skin, this can be broken up by agitation or removed chemically, as for instance in the titanium tetrachloride[14] and nitrogen plus chlorine[12] treatments of aluminium.

A second method of eliminating easily reducible gases like hydrogen lies, as is apparent from what has been said before, in oxidation of the metal. The difficulties in this case lie in oxidising to just the right extent to eliminate the hydrogen without causing trouble by over-oxidation and in introducing sufficient oxygen where oxygen solubility is low. Reitmeister[17] proposed a method of oxidation by the addition of a metallic oxide followed by reduction by means of carbon, but this necessitates striking the right balance between oxidation and "carburisation." Lepp[13 18] has taken the application of this principle a great deal further, particularly in the case of bronzes, by providing controlled oxidation by means of an oxidising slag. Excess oxidation is avoided by introducing into the alloy some readily oxidisable metal such as zinc, the oxide of which, formed in preference to other metallic oxides, is readily eliminated from the melt.

The avoidance of unsoundness due to reaction between oxygen and some readily reducible element, like hydrogen or carbon, has been discussed at some length, and the success which can be achieved in this direction by deoxidation of the melt prior to pouring depends entirely on the efficacy of the deoxidant employed. In this connection it must be remembered that the choice of deoxidants in non-ferrous work in particular is limited to those which form deoxidation products which can readily be eliminated from the melt. It has previously been suggested[19] that this applies almost entirely to elements which form fluid oxides or oxide slags, of which phosphorus, silicon and manganese are the most common. These have not anything like so high an affinity for oxygen as, for instance, aluminium, but alumina inclusions are in themselves seriously detrimental from many points of view. Where these elements therefore have not a sufficiently high affinity for oxygen, or a sufficiently low solubility of their oxides in the melt in question, other and more complex deoxidisers have sometimes been employed, as for instance the alkali and alkaline earth elements.

Most of the methods of degasification which are in industrial use, with in some cases highly successful results, depend on one or other of these principles, the application of which will, it is hoped, be clear from the brief outline of the subject given in this Paper.

TABLE V.—*Effect of Treating Aluminium and Aluminium Alloys with Steam.* (Hanson and Slater.[12])

Ingot No.	Material.	Treatment of molten metal.	Density.	Appearance.
5	U. "3L11" ..	None. Standard test casting	2.771	Moderate.
6	" ..	Atmosphere of steam for 1 hr.	2.728	Very bad.
7	" ..	Brisk stream of steam bubbled in for 1 hr.	2.221	"
8	" ..	Brisk stream of steam bubbled in for 3 min.	2.690	"
12	Virgin aluminium ingot.	None. Standard test casting	2.673	Practically sound.
13	"	Brisk stream of steam bubbled in for 3 min.	2.469	Very bad.
14	"2L5"	None. Standard test casting	2.934	Moderate.
15	"	Brisk stream of steam bubbled in for 3 min.	2.788	Very bad.

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Effect of Melting Conditions on the Properties of Castings

(*Concluded from page* 8.)

vacuum discharge tube with a high-tension electric current around 130,000 volts, but only a few milliamperes intensity. Metals when subjected to these conditions released gas, and the interesting thing to note was that the amount of gas set free was in surprising quantities. For example, a 100 grm. sample of pure aluminium (99.99 per cent.) liberated 192 ccs. of gas when tested by the discharge tube method at room temperature and only 20 ccs. when melted in a vacuum. The greater portion of the gas released was hydrogen (65 to 75 per cent.), followed by carbon monoxide (18 to 20 per cent.), nitrogen (3 to 7 per cent.) and carbon dioxide (2 to 6 per cent.). This clearly showed that heating metal in a vacuum alone was quite unsuitable for determining dissolved gas. Similarly, measurement of the gas absorbed by a metal in a closed system would not indicate the total gas in solution as the amount of gas residual before heating was unknown.

Mr. Moreau had carried Prof. Chaudron's work still further and published additional data last year in the form of a thesis from Lille University.

In this later investigation, metals other than aluminium had been tested for dissolved gas by the discharge tube method, and it would appear that the solubility of hydrogen in all the common metals was very much higher than the values given for example in Fig. 1 of Mr. Bailey's Paper. This new method of estimating the amount and nature of gas present could be usefully employed by investigators in this country.

Mr. W. C. Devereux's Paper would be of undoubted value to the light-alloy founder, and it was interesting to note the remarks relative to the value of the low-frequency induction furnace. There was no doubt that furnaces of this type (as well as the high-frequency unit) afforded simple and foolproof means for the production of metals of consistently high quality. The high-frequency furnace had, of course, the advantage that it would be completely emptied after each heat, which was useful where different types of alloys had to be handled.

Thanks were also due to Dr. Street, to M. Hajek and J. Koritta and also Dr.-Ing. R. Irmann for their contributions to this session.

MR. A. J. SHORE, seconding the vote of thanks, said he had thoroughly enjoyed the session, which he had attended because light alloys were making such rapid progress. The meeting was fortunate in having what was virtually the world at its disposal, and the authors deserved thanks for the trouble they had taken to put forward their views.

The vote of thanks was carried with acclamation and the session closed.

Institute of British Foundrymen

ELECTION OF NEW MEMBERS

At a meeting of the Council of the Institute of British Foundrymen, held in London at the Dorchester Hotel on June 12, the following were elected to membership:—

As Members.

A. D. V. Allan, chief engineer, Durban Falkirk Iron Company, Limited, Durban, S.A.; A. Augstein, London; S. Ayres, foundry manager, Shipman & Company, Limited, Hull; D. A. Chaytor, assistant to foundry manager, English Steel Corporation, Limited, Sheffield; E. Dennison, consultant, 57, Bricknell Avenue, Hull; J. H. Dobson, D.S.O., managing director, Dobson & Dobson, Limited, Webber Street, Selby, Johannesburg, S.A.; W. M. Doyle, Ph.D., foundry superintendent, Magnesium Metal Corporation, Limited, Port Tennant Works, Swansea; W. A. Gibson, foundry consultant, Bridge Road, Glebe, Sydney, Australia; J. Ikin, foundry manager, Thos. Broadbent & Sons, Limited, Huddersfield; R. E. Martin, director, Robson Refractories, Limited, Darlington; V. Moyle, proprietor, School Road Foundry, Hampton Wick, Middlesex; W. A. Musgrove, director, Renishaw Iron Company, Sheffield; R. H. Newton, sales representative, Luke & Spencer, Limited, Broadheath; E. H. Salinger, engineer, London; D. O. Sillars, joint managing director, Warner & Company, Limited, Cargo Fleet, Middlesbrough; D. P. Smith, moulder, L. Tomey, Limited, Birmingham; S. N. Wrightson, metallurgist, T. Summerson & Sons, Limited, Darlington.

As Associate Members.

W. A. von Albach, journeyman moulder, Umgeni Iron Works, Durban, S.A.; J. D. Fraser, patternmaker, P.O. Van Ryn, Benoni, S.A.; W. Kerr, foreman, Cruickshank & Company, Limited, Denny; R. E. Marsh, representative, Wm. Rowland, Limited, Sheffield; R. F. Miller, S. Russell & Company, Limited, Wolverhampton; A. E. Mudd, founder, H.M. Dockyard, Devonport; J. A. McIntosh, patternmaker, Smith & Wellstood, Limited, Bonnybridge.

As Associate.

W. N. Jones, foundry apprentice, Alfred Herbert, Limited, Coventry.

As Associate (Student).

P. Kirkham, engineering draughtsman, J. and W. Kirkham, Limited, Bolton.

Views on Cast Iron for Enamelling

By S. EVANS, M.Sc. (Brockhurst Castings, Limited)

(Paper read before a joint meeting of the Birmingham, Coventry and West Midlands Branch of the Institute of British Foundrymen and the Midland Section of the Institute of Vitreous Enamellers, Mr. L. W. Bolton and Mr. W. Todd (the respective presidents) acting as joint chairmen)

The author does not propose to give a detailed description of the manufacture of white porcelain-enamelled cast-iron baths, but to refer to the various processes and indicate what steps have been taken to overcome difficulties.

Pig-Iron, Scrap and Coke

The question of the best grade of pig-iron and the correct percentage of scrap to use has given rise to much discussion. Sellers of pig-iron have been able quite conscientiously to assure the author that one brand is definitely the best and that most manufacturers of repute are regular users. No technical reasons have been advanced in support of these views, for the simple reason none exists. Consequently, at various periods, and for various reasons quite unconnected with the excellence of these irons, the author has used various brands, and in no case has he been able to connect such change with any change in efficiency. One is therefore forced to the conclusion that under the present-day system of grading pig by analysis, the metallurgist should be able to choose his pig-irons without outside help. The same remarks apply to scrap, but in a lesser degree. From a personal point of view, light scrap is preferable, because it is cheaper, and, if it is of a constant composition, the main condition is that it shall be 90 per cent. iron and not 90 per cent. rust.

It must be remembered that light castings are under discussion, and thus a fairly high phosphorus is necessary, combined with a silicon content of over 2.75 per cent. Again, the industry has been told that manganese and sulphur are very important, and large-scale experiments have been conducted to reduce the latter, without any noticeable change in subsequent procedure being shown. It is therefore felt that one can to-day choose any brand of pig-iron to analysis, mix it with sorted scrap and feel confident of success. As regards coke, here one has to admit that there is a difference, and it was eventually decided to standardise on one of the more expensive cokes in order to yield a hotter iron at less cost. In amplification of this remark, it must be noted that the bogey of sulphur in coke does not affect the subsequent operations, the physical character of the coke apparently being the prime factor.

Preparation of Castings

It is not proposed to enter into the question of moulding except to say that the original hand moulding proved so unreliable that the author had to dispense with the system completely and substitute machine moulding. With regular control of sand, this method is far more consistent in the hands of intelligent men with no foundry traditions behind them.

The object of the foundry is to produce castings of normal surface as free as possible from holes, gutters, etc., and this is very largely a function of the sand and manipulation. The preparation of such castings for enamelling would appear to be governed by purely mechanical considerations. The rough castings are shot-blasted to remove adherent sand without any attempt thoroughly to clean them. They are passed to the dressers, who work with high-cycle electric grinders of the face and edge grinder type. Their function is to remove small knots of iron, gutters, etc., to make the edges straight, and to smooth off any flash left on the castings.

The dressed castings are passed through a final shot-blast where they should be given a thorough blasting to give a clean matt uniform surface from which all traces of dressing have been removed. No sharp angles should be left, as the enamel will very likely craze at these angles and flake off any smooth ground portions of the surface.

Enamel Preparation

Very little can be said on this subject as the author has discontinued making his own enamel. The ground coat is generally a simple mixture of borax, felspar and quartz, and is ground with clay additions in a wet mill till creamy and in a state of suspension. The cover coat is also a mixture of borax, felspar, cryolite, etc., with additions of antimony oxide (or sodium antimoniate) which is melted in a reverberatory or rotary furnace, quenched in water to crack the melt, removed from the water in perforated baskets, dried, and ground dry in ball mills with generally no additions to a state of fineness which varies with the customer's requirements. There would not appear to be any great mystery about enamel-making, in spite of the craze in this industry for "secret formulæ."

The predominant consideration throughout the process of enamel making should be absolute 99.9 per cent. cleanliness. The ideal is laboratory-like conditions, by which is not meant works laboratory but platinum crucibles for fusion (with lids), dust-proof drying and grinding, and these conditions are very difficult to attain in a works. They are, however, so nearly attainable as to give very little trouble, but constant supervision is necessary as bad lapses will occur.

Instruments have been devised and are used to determine with more or less accuracy all the physical properties of an enamel and the iron to which it is applied. The most elusive of these properties is the thermal expansion, a phrase which covers a multitude of sins.

If one has been running successfully for months, with the scrap in the region of 5 per cent., and a period of crazing is suddenly experienced, the enamel maker asks for a sample of the iron and reports that it is too high or too low in one constituent or another, that its expansion is so and so, and if the iron is to be stabilised according to sample, he will have to drop the expansion of his enamel by 5 points to accommodate it. Or the radii on the casting may have suddenly reduced themselves below the danger point.

If there be a sudden epidemic of black specks the enamel maker points out the existence of small drafts in the enamel shop, or that the castings are dirty and floating through, or there is some other possible explanation in the method or shop which the enameller must discover. It will be noted there is no possibility of the enamel varying, which of course is what is to be expected. Personal experience is:—

(1) The quality of the iron is only important in so far as the silicon is concerned, and anywhere between 2.75 and 3.1 per cent. is suitable. (A personal belief is that it is possible to make satisfactory castings from 100 per cent. scrap with ferro-silicon.)

(2) Black specks are due to impurities in the atmosphere both at the enamel maker's works and the enameller's works, because the author has sieved enamel as received and found quite a percentage of coarse frit, wood splinters, etc., in the bulk.

(3) Crazing very often occurs locally due to the very small margin of expansion allowed. It always finds the weakest part, generally on a radius or a thick part, and is worse in cold weather. The mechanism of glass cracking (when thick) in hot water makes an interesting comparison.

The writer has seen baths cooled slowly in insulated ovens, and has taken his own out into the warehouse when still hot, loaded them hot, and is forced to the conclusion that the technique of enamel smelting is not developed sufficiently highly.

There is no doubt that the enamel manufacturer is under a great handicap in not having the opportunity of applying his product under large-scale conditions, and the closest co-operation between maker and user is the only way to achieve uniformity and solve difficulties.

Application of Enamel

The method of application of the ground coat varies, but the ground coat is always applied wet either by pouring on, brushing on, spraying on or a combination. Before the ground coat is applied, the baths are carefully looked over and any small holes are filled with special clay which is smoothed off and the wet ground coat brushed and sprayed on. This coat is allowed to air-dry and is then fused at a temperature determined by the ground coat used. The casting is withdrawn at a temperature of about 900 deg. C., and the first cover coat of enamel is dusted on through a 40- or 60-mesh screen fitted with a pneumatic vibrator. The casting is returned to the muffle for fusing, withdrawn, a second cover coat dusted over the first, returned to the muffle for final fusing and placed on the floor to cool off. The ground coat takes 7 to 10 minutes to fuse, the first white coat 3 to 4 minutes and the second white coat 2 to 3 minutes. When cool the bath is transferred to warehouse, inspected for quality, and graded.

The *faults* which lower the grade of a bath are:—Crazing; pinholes; blue; waviness on sides or edges, and distortion.

A housing-scheme bath has a superficial area of 26 sq. ft. Thus the finished article must have 26 sq. ft. of surface which curves inwards and outwards, and be covered with a white opaque glass melted on to it. It must be absolutely continuous, not have one pinhole or craze line. It must have no black specks or waviness, and if during the first six months it shows a latent defect (always an enamel defect), it must be replaced.

In conclusion it is hoped that it has been possible to show that the application of enamel

to cast iron is not so dependent on a scientific control of the ingredients which go to make up the finished article. In as few words as possible an endeavour will be made to summarise the description of the whole set-up:—

Cast iron requires controlling as regards the most important constituent—silicon; phosphorus, sulphur and manganese are relatively unimportant in the proportions found in normal pig-iron and scrap. The silicon is only important in its effect on the carbon. There is no justification for the statements made by pig-iron salesmen that their iron is *the* best for enamelling.

Scrap should be controlled only in the sense that the same type of scrap is used at the same time. Primarily, the silicon here is again the all-important element. Secondarily, the amount of oxidation or rusting should not be excessive.

Coke.—The only criterion for coke is its capacity for producing heat (a physical characteristic). The sulphur content is not of prime importance.

Enamel is an empirical substance and its control is governed by the varying constitution of the natural products contained therein, the final form which the enamels assume due to time and temperature of fusing, and, most important, the cleanliness of the whole process from raw-material stores to the finely powdered enamel when in the linen bags. It must be understood that the scientific control which is exercised over the final formulæ is very important, but only because any actual major departure would make the enamel useless and therefore this point is taken for granted.

Working technique is the cause of practically all trouble. *Sand control* is essential to give good castings cooled as uniformly as possible in the moulds.

Pattern control is to help the same object—that is, *cleanliness* of the process from the rough casting onwards, especially in the enamel shop. Control of the fusion of the enamel as regards time, temperature and uniformity is essential. So too is careful handling of the enamelled bath until it is installed in its final resting place, as it is not fully appreciated that a bath is a very thin casting which can easily be bent sufficiently to damage the very thin coating of opaque glass which has been fused on to it and has not been carefully annealed.

DISCUSSION

MR. L. W. BOLTON thought all would agree that the lecturer had given a full and frank expression of his views. Much of what he had said was sound common sense. Apparently Mr. Evans was using a high-phosphorus pig-iron and was getting little trouble from cracking, and he wondered whether pig-iron of that type would not give an iron which was prone to cracking, and whether it would not be wise to reduce the carbon content.

MR. EVANS said he was glad to hear Mr. Bolton describe his remarks as being in the nature of common sense. As regards high silicon and high phosphorus and their effect on cracking as applied to the particularly large light castings he made, there was no doubt that the main reason for cracking was the non-uniformity of the sections.

Purpose of Annealing

DR. H. T. ANGUS could not quite see where Mr. Evans' views differed materially from those of the authorities. His final views seemed to be those generally held in industry at the moment. One factor which must be remembered about using scrap was the variation in foundry technique. He was interested to note that Mr. Evans said that castings left out in the open for a period required annealing to drive out moisture. Of course, there was possibly another explanation. Annealing helped to burn out the surplus carbon and at the same time drive out the moisture. He was somewhat puzzled as to how far sand-blasting really produced keying to which the enamel would adhere. He did not think the roughness of the surface had anything to do with it. The surface produced by shot-blasting was different from the rough surface sand-blasting would give.

MR. EVANS agreed with what Dr. Angus called the standardisation of foundry technique, because one must have at least some slight control of melting technique. His foundry technique was entirely confined to the periodical determination of silicon. He was afraid he could not agree with Dr. Angus that possibly annealing was not so much a question of driving out the moisture from the pores of the metal as burning off the surface carbon. If one annealed a casting it was covered with a certain amount of scale, and it was sand-blasted to remove that scale. Possibly it might decarbonise the surface, but the subsequent sand-blasting would remove the decarbonised section to such an extent as to expose the original grain of cast iron. With regard to the keying question, he had had the point submitted regarding sheet iron, which had a cold-rolled surface; but he wanted to make it clear that, broadly speaking, wet process enamels were applied. He would not presume to argue, because he did not know anything about them, and it was possible that the technique was quite different. His own theory about keying was that it had no relation with adherence between the enamel and the iron, but was purely a common-sense explanation.

Adherence and Contraction

MR. W. TODD, referring to the question of adherence, said he was interested in the application of wet enamels, and also in enamelling baths. In regard to pinholes it was his firm's practice to anneal all baths that stood for any definite period, particularly those cast on a Saturday. They found that it paid in the long run in regard to the wet process. He did not agree with Mr. Evans in his attempt to reduce it to a mathematical problem, as he was always of the opinion that the reason for using a ground coat was to obtain adherence.

MR. EVANS explained that crazing was not really a question of adherence between the enamel and the cast iron, but of different rates of contraction. Frankly, he did not know anything about adherence between cast iron and enamel. The ground coat was put on to keep the iron away from the enamel and to prevent graphite flakes from reacting with the oxides in the enamel. He would be the last man in the world to say that pinholes were not caused by bubbles coming from the iron. He had experienced periods when from 20 to 25 per cent. of the articles enamelled suffered from pinholes, but had definitely cured them by changing the fusing times. He thought he could say that in enamelling 90 per cent. of the secret of success was time and temperature rather than ground coats.

Carbon Content and Pinholing

MR. H. G. GREENWOOD asked if the lecturer could enlighten him with regard to pinholes in the wet enamelling process. Further, Mr. Evans had not said anything about the carbon content of his iron. He agreed with him in regard to silicon, and would like an expression of opinion about the carbon content in connection with the annealing process.

MR. EVANS pointed out that, while there was a decided difference between wet and dry enamelling of cast iron, he did not know whether the difference in the chemical composition of the enamels was an essential one, and he would think the reactions were much the same. He did not place any great importance on the total amount of carbon present in cast iron or on the percentage of graphite as compared with the percentage of cementite except that the combined carbon content should not become too high. He thought it reasonable to say that, so long as the total carbon was in the neighbourhood of 3.5 to 3.8 per cent., it would be satisfactory. However, it was possible for trouble to arise if the graphite existed as coarse flakes, but they were eliminating pinholes without controlling the size of graphite flakes. To attempt to control the total carbon by the addition of steel or low-phosphorus pig-iron would tend to a much greater variation than that introduced by working two hours' overtime.

Mechanism of Adherence

MR. F. PEARCE raised the question of fusion and adherence, and asked how thick the enamel could be laid on. Further, was it always unavoidable that, under the skin, there were blow holes?

MR. EVANS thought it was almost certain that the moment there was adherence between the ground coat and the iron there was fusion between the ground coat with pieces of the iron, and that the back of the ground coat would almost certainly dissolve a certain proportion of the oxide of iron generated by the iron. Whether there was a transfer stage between that oxide of iron through the lower oxides into the iron was a moot point. The probability was that adherence was caused by the microscopic roughness of the surface due to oxidation, which would not be uniform. Immediately a cover coat was put on, there was a merging of the two coats and fusion through each, with a great deal of merging from the pure iron to the pure enamel on the surface.

The thickness of the enamel varied, but $\frac{1}{16}$ in. could be assumed to be average. It would vary on different parts of the same castings, but, from the point of view of crazing, the finer the enamel the better it was. In regard to blow holes, it was almost certain that no coating of dry-dusting enamel was free from blow holes. If a dry-dusted casting with $\frac{1}{16}$ in. enamel was taken and a section 2 in. long examined, he should be surprised if, at a magnification of 60, they did not find that the enamel was discontinuous and had holes in it.

Graphite Size and Silicon

DR. G. T. O. MARTIN made reference to the size of graphite, and expressed the opinion that it was most important for wet enamels. Mr. Evans' silicon content was a bit higher than that used by most practical enamellers, because high silicon gave a more porous iron. He fully agreed that they could not get much out of calculation, but measurement of expansion was useful and was actually used by several firms of enamellers in Scotland. As regards the expansion behaviour of dry enamel, it was found that measurement afforded an adequate routine check. The dry process enamel had but little latitude in physical properties and required more control in manufacture. Mr. Evans suggested that the chief function of the ground coat was to prevent the oxidation of the metal, but he would like to know what happened if the ground coat was over-burned.

MR. EVANS agreed that the size of the graphite might be important in the wet process of enamelling. One would be foolish to deny scientific facts, but he could only speak with confidence of his own particular process, and in that regard he would say that, taken in conjunction with the statement that his silicon was rather higher and would tend to give a coarser graphite, he ought to be subjected to more trouble than most people. That was not a fact. He imagined that Dr. Martin was right in saying that dry process enamels allowed little latitude in comparison with the wet process, because a great deal more wet enamelling was done than dry enamelling. He did not think there was any argument against his contention that the ground coat prevented oxidation of the metal. At the same time he would rather like to modify that by saying that oxidation of the iron could not be prevented. Probably the chief function of the ground coat was to dissolve the small amount of oxide of iron which could not be eliminated otherwise. If they tried to dry-enamel cast iron without a ground coat, they would fail.

On the proposition of MR. A. J. SHORE, seconded by MR. SHOTTON, a hearty vote of thanks was accorded Mr. Evans for his Paper.

Investigation and Modern Ideas on Enamel Control

By G. H. ABBOTT, B.A. (Oxon), A.I.C.

(*Continued from page 447, vol. 60.*)

Viscosity of Enamels

The fusibility of enamels depends, of course, upon their chemical composition, but unlike definite compounds they show no marked change of state, gradually becoming more fluid with rise of temperature. Andrews in his book describes the various methods which are used for estimating this property, and a critical analysis of them has been made by the Bureau of Standards at Washington. The only satisfactory way is actually to measure the viscosity of the molten enamel over the range of temperature required. Measurements for glasses have been made up to 1,400 deg. C. and for fused slags up to 1,600 deg. C., and in these investigations the experimental difficulties of working at high temperatures have been largely overcome. American physicists have recently studied the viscosities of some commercial enamel frits up to 1,000 deg. C., and their report has been fully reprinted in the technical journals here. This investigation is another interesting application of one of the methods of glass technology, but it would have had a more permanent value if the analyses of the frit compositions had been given. For future studies also it would be useful to extend the measurements of viscosity to the temperature of the fritting kiln.

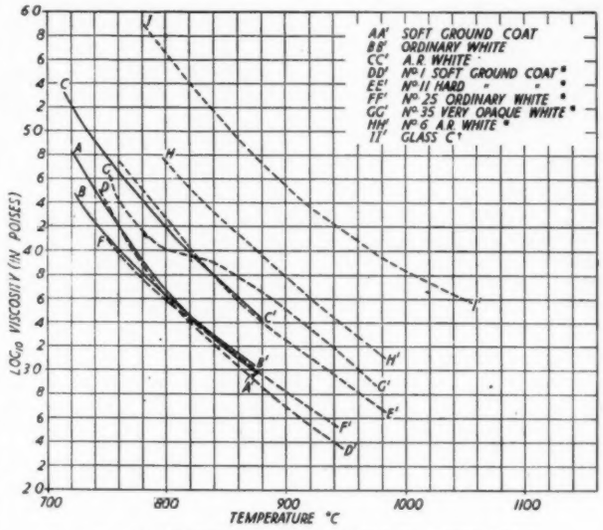


FIG. 5.—VISCOSITIES OF MOLTEN SHEET-IRON ENAMEL FRITS.

Some months ago the writer was interested to know what results for enamels could be obtained with a rotating cylinder viscometer designed for measurements on ordinary glass. Mr. A. Bunce was good enough to make the measurements for three commercial enamel frits, and the United Glass Bottle Manufacturers, Limited, have courteously given their permission to publish the results (Table II).

The results are usually plotted in the form of curves, connecting the temperature with the common logarithm of the viscosity in poises. This has been done in Fig. 5, and the results of the ground coat, white and acid-resisting white are represented by the curves AA^1, BB^1 and CC^1 respectively. The experimental points lie on a smooth curve, and it is important to note that the curve for the acid-resisting white enamel lies considerably above that for the ordinary white enamel and approximately parallel to it. The other curves DD^1, EE^1, FF^1, GG^1 and HH^1 shown by dotted lines are the results obtained by the American workers referred to above. For comparison also curve II^1 gives the viscosity of an ordinary glass.

In Mr. England's Paper to which reference has already been made the factors determined by Winklemann and Schott for calculating the moduli of elasticity of glasses are quoted, and these he says can be applied to vitreous enamels. It would appear, however, from the work of F. P. Hall on the mechanical properties of over a hundred different compositions that the factors for an oxide constituent depend not only on the amount of that oxide present, but also on the kind and amounts of other oxides present in the same frit. If this be true enamellers may find it more satisfactory practice to determine experimentally the elasticity moduli and other mechanical properties of enamels.

In this connection the work done and the methods used for glasses by G. Gehlhoff and M. Thomas may serve as a guide. A few measurements of these properties for enamels have been made in America, but up to the present the results are not conclusive.

Acid-Resisting Enamels

A high degree of acid-resistance in enamels is not usually required, but it is important for domestic use that they should be able to resist the staining effect of foods. Acid-resistance in enamels depends like the other properties on chemical composition, and the absence in the frit of any compounds easily hydrolyzed should be of prime importance. No guiding rule exists for enamels, but it would be interesting to know how far Lulkowski's principle for glasses and T. E. Thorpe's ratio for glazes are true for enamels.

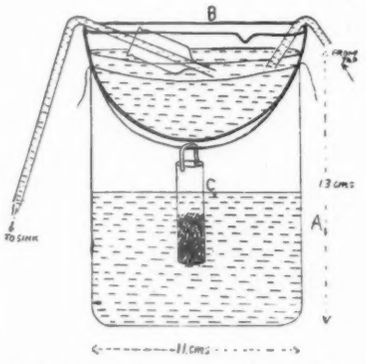
Standards for acid-resistance are at present under consideration by a technical sub-committee of the Institute, and the subject was also referred to by Mr. Pearce and Dr. Martin. As with glass the resistance to attack may be measured either on the milled frit or the finished article, and several methods have been described. For a systematic study of the acid-resistance of enamels as influenced by their composition, the method described by Miss Dimbleby has been used. A sample of the graded frit is contained in a 100-mesh platinum gauze basket (Fig. 6), and suspended from platinum wire in a beaker of the boiling acid solution. A silica basin acts as a condenser. The resistance is measured by the loss in weight of the frit.

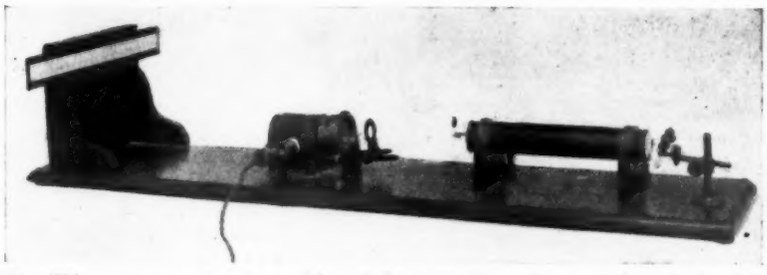
TABLE II.—*Viscosities of Enamel Frits.*
(By courtesy of United Glass Bottle Manufacturers, Limited.)

Sheet iron ground coat.		Sheet iron white.		Sheet iron acid-resisting white.	
Temp. Deg. C.	Visc. in kilo-poises.	Temp. Deg. C.	Visc. in kilo-poises.	Temp. Deg. C.	Visc. in kilo-poises.
721	63.1	724	29.5	715	214.0
737	38.9	755	11.2	745	70.8
766	13.2	776	7.1	779	26.9
791	5.8	802	4.2	824	8.7
815	3.3	832	2.2	839	6.5
856	1.3	839	1.8	852	4.8
876	0.96	873	1.1	881	2.7

The melting of an enamel in any container other than a closed crucible raises difficult problems of control. The materials lost by volatilisation and blast depend on the temperature, the design of the fritting kiln and the composition of the enamel. Frequently proper temperature control is impossible, and the process is dependent entirely on the skill of the operative. In a study made by Poste and Rice on the effect of degree of smelting on the properties of a frit, it was determined by analysis that boric oxide, sodium oxide and potassium oxide are progressively lost, resulting in a large apparent increase in the percentage of silica. This may lead to a substantial decrease in the coefficient of expansion of the frit. Some glass manufacturers actually use determinations of expansion coefficients for control of their melting tanks. By the courtesy of the General Electric Company, Limited, some results obtained at their Osram Lamp Works are given.

Commenting on these results Mr. R. W. Douglas writes: "We aim to keep the coefficient





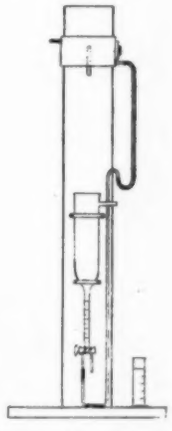


FIG. 6 (LEFT).—CHEMICAL RESISTANCE TEST FOR GLASSES AND ENAMELS. (*Courtesy Prof. W. E. Turner, Dept. of Glass Technology, Sheffield.*) FIG. 7 (BELOW).—EXPANSION APPARATUS. (*Courtesy of Research Laboratories of General Electric Co., Ltd.*) FIG. 8 (RIGHT).—"NAMELL" ELUTRIATION APPARATUS.

of expansion of the glass in our tank between 9.55 and 9.75 × 10^{-6}, although any definite trends within these limits are watched closely. The increase in expansion about the middle of the period (Table III) was found to be due to a decrease of about 20 deg. C. in the temperature of the tank, which reduced the amount of alkali lost by volatilisation; adjustment was made of the alkali content of the batch." Routine expansion measurements at the Osram Lamp Works are made by comparing the expansion of

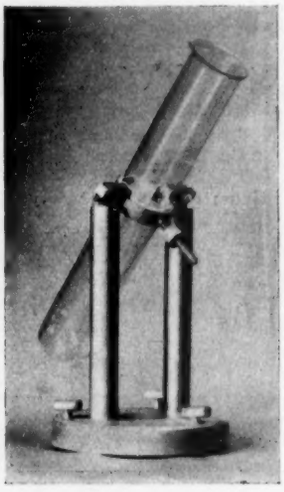


Fig. 9.

a test sample of glass with that of a standard glass rod of similar properties. The measurements are made only at two temperatures, room temperature and about 300 deg. C.

The testing apparatus (Fig. 7) is approximately the same as that of the standard apparatus (Fig. 3). Observations can be repeated with the same standard rod to ±0.2 per cent., and one standard rod suffices for about 20 tests.

For the titration of pickle acid by standard caustic soda solution it is frequently stated that methyl orange can be used as an indicator. It is the author's experience that no sharp end-point is obtained because of the presence of iron salts, but it is found that the first permanent precipitate of ferrous hydroxide gives a satisfactory result. With the acid at constant

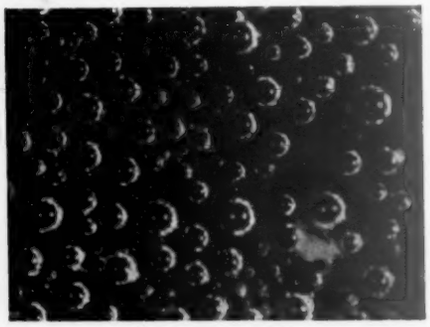


Fig. 10.—Photomicrograph of Normal Cobalt Ground-Coat Surface.

strength the rate of accumulation of dissolved iron salts can be followed simply with a Twaddle's hydrometer.

Slip Fineness Control

The Transactions of the Ceramic Society record many investigations by potters on the fineness distribution and milling of their materials. The same interest has been shown by refractory manufacturers, but apart from brief investigations in America, enamellers have not studied the problem. The fineness distribution of the milled enamel is a good indication of the efficiency of milling; it governs the rate of settling of the slip, influences its consistency and has an important bearing on subsequent processes. It is most conveniently determined by elutriation with water.

The oldest form of elutriator is that due to Schöne (about 1870), and is still in use to-day for

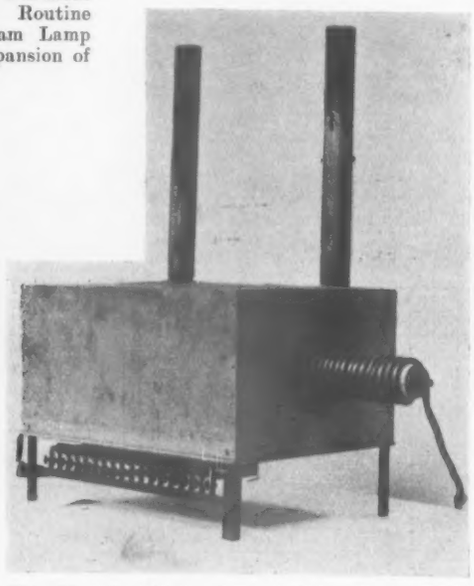


Fig. 11.—Gas-Fired Tubular Muffle Furnace.

the analysis of soils. Schöne's apparatus was modified and used during the last century by the eminent German ceramist, Hermann Seger. Its original form is well described by W. Jackson and E. M. Rich. For the separation of

Table III.—*Routine Expansion Measurements.*

Date of test.	Observed expansion coefficient. × 10^{-7}.	Departure from mean. × 10^{-7}.
1938.		
May 16	288.6	− 0.9
May 23	287.7	− 1.8
May 26	291.0	+ 1.5
May 31	289.8	+ 0.3
June 9	292.5	+ 3.0
June 13	291.6	+ 2.1
June 16	288.0	− 1.5
June 20	287.1	− 2.4
June 27	286.8	− 2.7
July 4	286.8	− 2.7

materials into three fractions the elutriator described by J. F. Krehbiel is a useful form of the apparatus.

In the factory a screen test based on a recommendation of the American Ceramic Society

Fig. 12.—Normal Ground Coat Fused in Nitrogen.

is commonly used for controlling the fineness of milling. Details of the test have been given by Mr. B. B. Kent in a Paper on mill room practice. At National Enamels, Limited, there is a simple form of elutriator—a more convenient testing apparatus. The apparatus, illustrated in Fig. 8, consists of a glass vessel about 9 in. long and 2½ in. diameter, tapered at the bottom and provided with a two-way stop-cock. Water flows from a constant-head tank through the sample of enamel contained in the vessel, carrying the finer fractions to waste. When the elutriation is completed the volume of residue is read off at the bottom of the apparatus. The test for ground-coat enamel takes 5 min. at a linear velocity of 3.240 mm. per sec., and for white enamel 10 min. at 2.225 mm. per sec.

The rate of settling of a suspension is conveniently investigated by measuring the rate of change of the centre of gravity of a cylinder of the material. In the apparatus (Fig. 9) designed by R. H. Whillock, of the South Metropolitan Gas Company, the enamel is contained in a test-tube balanced out of vertical on agate pivots. As the solid material settles out the test-tube gradually assumes a vertical position, and by the reflection of a beam of light from a small mirror carried on the horizontal arm of the apparatus, the rate of settling can be measured.

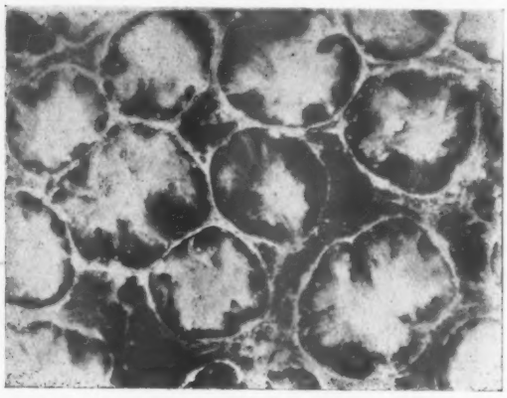


Fig. 13.—Photomicrograph of Enamel Surface after Pre-Oxidation of Iron and Fusion in Nitrogen.

The problem of measuring and controlling the consistency of enamel slips has been widely investigated, without very practical results. Mr. F. H. Clews discussed the subject in a Paper to the Institute three years ago. The simple form of Bingham plastometer—a burette with the lower end cut off and replaced by a rubber bung carrying a capillary tube of convenient length and bore—may be satisfactory for research work, but is hardly suitable for routine tests. The results expressed in terms of mobility and yield-value also take no account of the thixotropic nature of enamel suspensions. In works practice the difficulty of maintaining enamel at constant consistency is usually overcome by keeping a constant check on the weight of application per unit area.

Rivalry amongst suppliers of raw materials has led to the development of many new mill additions. Tin oxide now competes with zirconium compounds, cerium oxide and sodium antimoniate as an opacifier. New setting-up agents have been added to Epsom salts, and bentonite is frequently used instead of a full addition of clay. These materials are usually of high-grade quality.

Firing Enamels

The process of firing enamels on to the metal surface has probably received more attention from research workers than any other. Its problems have been investigated by steel manufacturers, frit makers and enamellers alike. In Germany, America and Scotland the phenomenon of the adherence of cobalt ground coats to sheet steel has been pursued by scientists at universities and technical colleges, with the knowledge that a white ground coat is the Philosopher's Stone of the enamelling trade.

The source and nature of the gas bubbles which are always present in a normally fired ground coat (Fig. 10) have also been investigated. Oxygen, nitrogen, hydrogen, carbon monoxide and carbon dioxide have been identified by spectrographic and micro-analytical analyses.

The interesting experiments of R. D. Cooke have been repeated by the writer's company in conjunction with the South Metropolitan Gas

(*Continued on page* 18.)

J·G·&S

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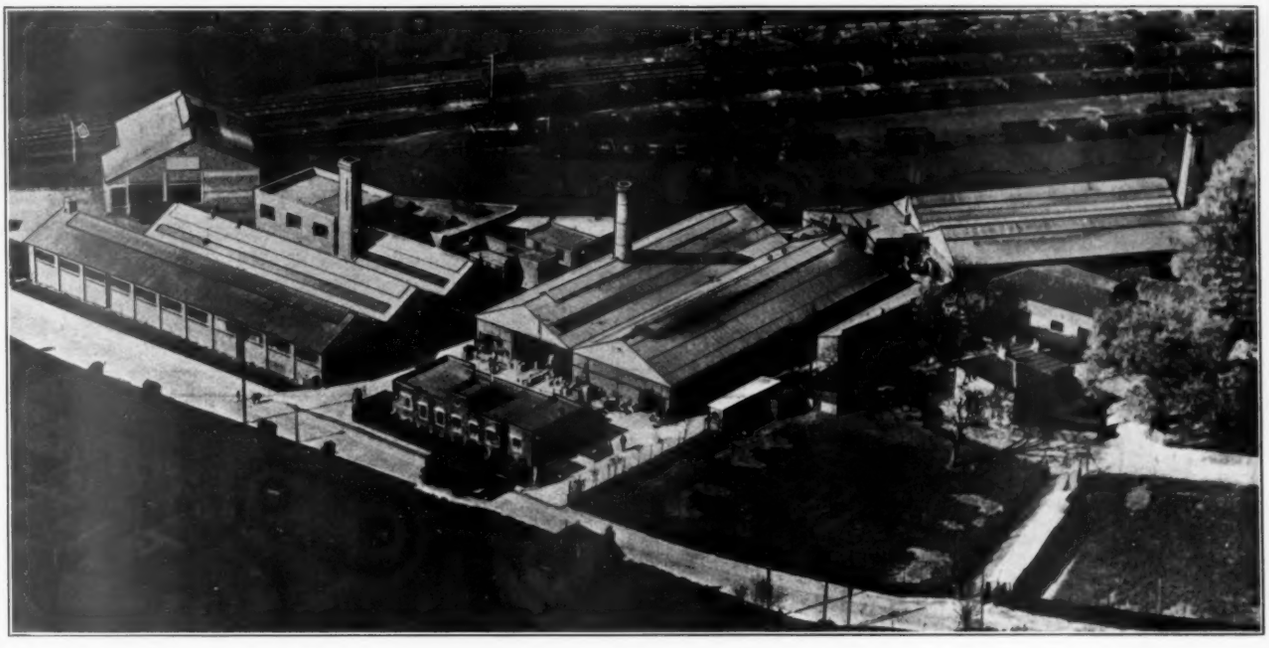

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The Week's News in Brief

Trade Talk

FACTORIES in Coventry closed down last week for a holiday in place of the usual break in August.

SOME 43,000 WORKERS in Government engineering shops are to have their wages increased by 2s. a week.

REDPATH, BROWN & COMPANY, LIMITED, have received the contract for the major part of the steelwork for the new Rolls-Royce aero-engine factory at Hillington.

THE TOWER OF EMPIRE at Bellahouston Park, Glasgow, has been sold by the Empire Exhibition authorities to George Cohen, Sons & Company, Limited. Demolition will commence immediately.

THE SWEDISH trade delegation whose visit is sponsored by the Federation of British Industries arrived in London on Monday, and have begun conversations directed to the strengthening of British exports to Sweden. Among the products to be discussed are pig-iron, rolling mills, electric furnaces, textile machinery and machine tools. Mr. Oliver Stanley (President of the Board of Trade) is to preside at the dinner which is being given by H.M. Government at the Savoy Hotel to-night (Thursday).

THE RECENT STUDY COURSE in vitreous enamelling (the first of its kind) organised by the Joint Committee on Vitreous Enamelling of The Institute of Vitreous Enamellers and the British Cast Iron Research Association, attracted over 100 members of the two bodies and was highly successful. Held in Birmingham, ten lectures were given, designed to cover the whole field, by Mr. A. D. Biddulph, Mr. H. Cowan, Mr. T. J. McArthur, Mr. H. D. MacLaren, Dr. G. T. O. Martin, Mr. L. R. Mernagh, Mr. J. G. Pearce, Mr. T. Tyrie and Mr. S. W. Vickery, followed in each case by active discussion. Four practical demonstrations were also given by courtesy of and arrangement with Ferro Enamels, Limited, at their laboratories near Wolverhampton, on the preparation of metal surfaces, milling of frit and mill additions, the application and fusing of enamels, and control and inspection, including apparatus and tests. The course covered both wet and dry processes, as well as enamelling of sheet and castings.

THE APPROACH of the two large-scale black-outs which are to take place on the nights of July 13 and August 9 lends additional emphasis to the urgent request of the Lord Privy Seal that the occupiers of all factory premises, of whatever size and wherever situated, should consider as early as possible the matter of their preparations to obscure lighting in the event of war. The Civil Defence Bill lays a general obligation on commercial and industrial establishments to make such preparations, but the hope has frequently been expressed that they would not wait for the Bill to become law but would push forward their preparations as much as possible in the meantime. A complete black-out is essential in war-time, and industrial production would be seriously interrupted if arrangements had not been previously made to secure the obscuration of industrial lighting. Incidentally, a preliminary memorandum on the "Organisation of Air-Raid Precautions Services in Industrial, etc., Undertakings, and on the Training and Equipment of Personnel," has been prepared by the Air-Raid Precautions Department of the Home Office, and was published by H.M. Stationery Office last week (price 3d.).

Vitreous Enamellers' Annual Conference

Arrangements for the 6th Annual Conference of The Institute of Vitreous Enamellers, to be held at the Grand Hotel, Birmingham, on September 22, 23 and 24 next, are now being made by the Conference Committee. The provisional programme is tentatively arranged to allow the annual general meeting and the annual banquet to be held on Friday, September 22, with works visits to various enamelling plants in the Midland area. On Saturday, September 23, technical Papers will be discussed, and a theatre party is planned, followed by supper. A works visit in the Midland district is being arranged for the Sunday. Full details will be issued shortly.

Personal

MR. DONALD M. ROBERTSON, a former works manager of Etna Foundry, Falkirk, has been appointed foundry works manager at the Thorncliffe Works of Newton Chambers & Company, Limited, Sheffield.

MR. JAMES BUSSEY has been appointed a director of Thos. W. Ward, Limited, Sheffield. For 37 years he has been connected with the structural steel department. Mr. C. A. Lee, who for nearly 30 years has been connected with the loco and crane department, has been appointed a local director of the company.

MR. H. H. BERRESFORD has been appointed deputy managing director of the Staveley Coal & Iron Company, Limited, of Chesterfield. Mr. Berresford has successively held the positions of cashier, registrar, assistant secretary, assistant general manager and commercial manager, and he was appointed a director of the company in January, 1936. He is well known in the coal, chemical and pig-iron trades, and is chairman of the Foundry Pig-iron Producers' Association. He is a J.P. for the County of Derby.

MR. H. H. BERRESFORD.

MR. F. A. MARTIN, B.Sc., A.I.C., has been elected to the board of directors of Samuel Osborn & Company, Limited, of Sheffield. Mr. Martin joined the staff of the company in May, 1937, having previously been engaged since 1922 on the technical staffs of the Associated Lead Manufacturers, Limited, and other firms in the same trade. He was born in Jamaica, of Scots parents, and received his education at George Watson's College, Edinburgh, and Edinburgh University, and served with the R.F.C. and R.A.F. from 1917 to 1919, attaining the rank of Captain.

MR. W. B. LAKE, J.P., governing director of Lake & Elliot, Limited, Braintree, and President of the Institute of British Foundrymen, was entertained last Friday by the 750 workmen employed by the firm, and was presented with a silver salver and a silver tankard to mark his 70th birthday. Mr. J. B. Whitfield, a director of the firm, presided, supported by other directors and friends. Mr. E. Clarke, the oldest member of the staff at the works, who made the presentation, said he had started with the firm 43 years ago, when the employees numbered under 30. He said that all connected with the firm were pleased that Mr. Lake had been elected President of the Institute of British Foundrymen this year. Mr. Lake, expressing his thanks, mentioned that the business was started with two men and a boy, and said that the company was so successful because directors, staff and workmen worked harmoniously together to produce the best.

Wills

BUTLER, JAMES, of Lincoln, retired iron-founder £19,964

Obituary

MR. W. WARING, senior partner in the business of Waring Bros., chaplet and stud manufacturers, of Barnsley, died suddenly on June 30.

Company Meetings

Allied Ironfounders, Limited

Favourable results in spite of difficult trading conditions were reported at the annual meeting of Allied Ironfounders, Limited, held in London on June 28. MR. ALEXANDER W. STEVEN (chairman) said that normal business was inevitably affected by the constant recurrence of international crises. As a consequence confidence was shaken, resulting in a decline in house building by private enterprise and the building programmes of local authorities being curtailed, more particularly after the September crisis. The decline in demand for their goods led to more acute competition, with the result that prices deteriorated in some sections. Export business was more difficult than ever. The policy of self-sufficiency, exchange control and subsidised exports adopted by competing countries resulted in serious restriction of sales. The value of their own exports declined by 15.37 per cent. on the year. During the year they had, therefore, experienced a combination of circumstances detrimental to profits, reduced demand, increased costs, and increased competition. In the absence of any mitigating features the effect on their earnings would have been much greater than it had in fact turned out to be. Their turnover had declined, but not to such an extent as seemed probable in the conditions which prevailed. Having due regard to all conditions the directors were of opinion that the results were distinctly favourable. During the Great War many of their companies were very fully engaged on the production of munitions, mainly composed of high-duty cast-iron. They kept in close touch with the supply departments of the Government, but so far there had been no demand for munitions of this class.

Contracts Open

Doncaster, July 12.—Supplying and laying of three-quarters of a mile of 12 in. dia. cast-iron pipes and taking up the same length of pipes, for the Town Council. The Water Engineer, 2, Priory Place, Doncaster.

Halifax, July 15.—1,300 yds. of 10 in. dia. concrete-lined spun-iron pipes, to B.S.S. Class "D," for the Waterworks Committee. Mr. Percy Saunders, town clerk, Town Hall, Halifax, Yorks.

Newcastle-upon-Tyne, July 14.—Two cast-iron sectional low-pressure heating apparatus boilers, for the Education Committee. Mr. Thomas Walling, director of education, Education Office, Northumberland Road, Newcastle-upon-Tyne, 2. (Fee £5, returnable.)

Sheffield, July 31.—30-ton maximum capacity electrically-operated travelling crane, for the Town Council. The General Manager, Commercial Street, Sheffield. (Fee £2 2s., returnable.)

Singapore, August 8.—Straight pipes of internal dia. of 3 in. to 12 in., inclusive, and cast-iron specials in various sizes from October 1, 1939, to September 30, 1940, for the Singapore Municipal Water Department. (D.O.T. reference: T. 23.749/39.)

Light-Castings Industry and Rearmament

Mr. Burgin, Minister of Supply designate, received on June 27 a deputation representing the light-castings industry. Introduced by Mr. Tom Johnston, M.P., the deputation consisted of Mr. A. G. Logan, chairman of the joint committee of the Light Metal Trade Unions; Mr. George McLaren, ex-president of the Ironfounding Workers' Association; Mr. Robert Dickson, chairman and managing director of the Lion Foundry Company, Limited; Mr. William Rennie, chairman of Federated Foundries, Limited; Mr. J. K. N. Davis, director of Radiation, Limited; Mr. W. T. Wren, director of Allied Ironfounders, Limited, and Mr. W. R. Blair, chairman, British Ironfounders' Association and director of the National Light Castings Ironfounders' Federation.

The deputation put before the Minister suggestions for the employment of the industry's productive capacity in connection with the rearmament programme and urged the desirability of exploring the uses to which cast-iron might be put in time of war.

Specify CUMMING'S

SHALAGO (highest in Carbon)
COAL DUST
PARTING POWDER
TERRA FLAKE
BLACKLEAD and
FOUNDRY REQUISITES

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The Cumming
FURNACE
Melts Brass in 15 minutes

•

The Cumming
HAND RAM
MOULDING MACHINE

•

The Cumming
ELECTRIC RIDDLE

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Head Office and Works—
KELVINVALE MILLS,
MARYHILL, GLASGOW.

FOUNDRY BLACKINGS

•

PLUMBAGO
IMPORTED DIRECT FROM CEYLON

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Raw Material Markets

Consumers of foundry pig-iron have displayed little desire to take up additional tonnages and existing contracts are more than sufficient to meet their restricted requirements. Current new business is confined to small parcels for immediate delivery. The steel market goes from strength to strength and production last month was well maintained.

Pig-Iron

MIDDLESBROUGH.—It is fortunate for iron producers that there is plenty of business coming through for descriptions of iron other than foundry material, as the demand for the latter is very quiet indeed, with few indications of any early change. Makers are for the most part engaged on the production of basic iron and only a small output of foundry iron is resulting from intermittent working on this material. Trade in hematite, which has been rather dull for the past few weeks, has now opened out and consumers have placed orders for the delivery of heavy tonnages now that the reduction of 5s. per ton has been allowed since July 1, making East Coast mixed numbers 115s. for delivery on the North-East Coast, 120s. 6d. in Sheffield, and 126s. in the Midlands, all less 5s. rebate. Most works have still substantial stocks of iron on hand, but it is hoped that the current heavy demand will be maintained and that stocks will be reduced to a low level within a comparatively short time. Export trade continues to be negligible, as, despite the reduction in the price in this district, supplies are available elsewhere at lower figures.

LANCASHIRE.—There has been only a small amount of new business available in the foundry-iron section of the market during the past week and long-period buying does not find much support. The number of small parcels changing hands is quite considerable and the aggregate turnover is a fair tonnage. Machine-tool works and also heavy electrical concerns are busy, but most other iron-consuming firms' consumption is unsatisfactory. Offers of Derbyshire and Staffordshire brands of No. 3 foundry iron for delivery in the Lancashire price zone are on the basis of 104s., less the 5s. rebate offered to customers who conform to the conditions, with Northamptonshire No. 3 at 102s. 6d. The demand for hematite iron has broadened out considerably since prices were reduced on Saturday last, and trade may be expected to improve further, as consumers generally are well employed.

MIDLANDS.—The feature of the market in this area during the past few days has been the marked expansion in the call for supplies of hematite, the price of which was reduced by 5s. as from the beginning of this month. During the last days of June consumers placed orders for heavy tonnages for delivery after July 1 and makers' stocks should be considerably reduced in the near future. The call for supplies of high-phosphorus iron, on the other hand, continues to be rather unsatisfactory; prices have not been fixed for any definite period and current quotations are 101s. for Derbyshire No. 3 and 98s. 6d. for Northamptonshire No. 3, less 5s. rebate, delivered Birmingham and Black Country stations. Consumers of low-phosphorus iron are not showing quite the same interest in new business that they did a few weeks ago, as they are now well covered, but consumption is maintained satisfactorily and is likely to be continued for a long time to come, as many consumers have substantial orders on hand in connection with rearmament.

SCOTLAND.—The price of Scotch foundry iron was recently reduced by 5s. per ton, but still new business involves only small tonnages for prompt delivery. Five furnaces are producing foundry iron, six basic iron and two hematite. No. 1 foundry iron is now quoted at 103s., with No. 3 at 100s. 6d., both f.o.t. furnaces. Foundries in the Falkirk district are at present idle, having closed down at the end of last week for the annual holidays, which are expected to last for anything from ten to fourteen days, owing to the slack condition of trade. The Glasgow Fair holidays are due to commence shortly and the steelworks are meantime working to capacity in order to meet consumers' requirements. Hematite mixed numbers are quoted at 115s. 6d., and basic at 92s. 6d., less 5s. rebate, delivered works.

Coke

Prices of foundry coke have been stabilised up to the end of the year and some consumers are taking advantage of this by booking ahead. For delivery in Birmingham and district, the minimum price of best Durham coke and Welsh coke is 50s. 6d. per ton.

Steel

It is understood that during the past few weeks a number of British tramp steamers have been chartered for the transport of steel billets from New South Wales to ports in the United Kingdom: in fact, it is believed that about 150,000 tons to 170,000 tons have been involved. The steel is being supplied by the Australian Iron & Steel Company, an associated concern of the Broken Hill Proprietory Company. Galvanised steel sheets are also understood to have been despatched from Australia. In view of the shortage of certain descriptions of steel in the United Kingdom the arrivals of material from Australia will be welcomed. Meanwhile, all sections of the steel industry continue to work to capacity and most works have sufficient orders to last them for many months if no additional contracts are entered into.

Scrap

It has been announced that there will be no change in prices of steel-making descriptions of scrap before October 31; this was decided upon at a joint meeting of the British Iron and Steel Federation and the National Federation of Scrap Iron and Steel Merchants. Supplies of steel scrap from the United States are now arriving in this country fairly freely and the material is being keenly awaited in order to relieve the shortage of home-produced scrap. Supplies of iron scrap are also difficult to obtain in some areas, but in many cases foundrymen are well covered and are not now being seriously inconvenienced.

Metals

Copper.—Conditions in this market have remained quiet and business has been rather desultory, hand-to-mouth buying being favoured as against long-term contracting. Consumption is believed to be well maintained, but the uncertainty of the future is undoubtedly the factor which is withholding consumers' support at the present juncture. The lack of information of a reliable character with regard to Germany's intentions as to the future of the Free City of Danzig and the Polish Corridor will inevitably continue to restrict business in the commodity markets, though crises are now accepted without much disturbance on the markets. Many copper consumers are connected with the rearmament programme in some way or another and it is suggested that these concerns will be badly situated when this work is completed or reduced from its present high level; this will undoubtedly be so to some extent, but it is reassuring to hear that the Government has not lost sight of the fact and that it is making provision as far as possible for eventualities. United States exports of refined copper during May amounted to 32,029 short tons, of which Japan took 13,868 tons, Italy 4,632, Germany 3,420, France 2,977, Poland 2,371, and Great Britain 1,597 tons. Exports of copper scrap for the same month totalled 1,330 tons, of which Germany took 561 and Japan 402 tons.

Copper prices in London rose sharply on Monday on the report that France had bought 21,000 tons of copper in New York at the end of last week for war reserve purposes and was likely to increase her purchase to a total of 50,000 tons. The copper is said to be of non-United States origin.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £42 3s. 9d. to £42 5s.; Friday, £42 6s. 3d. to £42 8s. 9d.; Monday, £42 13s. 9d. to £42 15s.; Tuesday, £42 11s. 3d. to £42 12s. 6d.; Wednesday, £42 15s. to £42 17s. 6d.

Three Months.—Thursday, £42 10s. to £42 12s. 6d.; Friday, £42 13s. 9d. to £42 15s.; Monday, £43 1s. 3d. to £43 2s. 6d.; Tuesday, £42 18s. 9d. to £43; Wednesday, £43 2s. 6d. to £43 3s. 9d.

Tin.—It is expected that the buffer pool will have to be drawn upon in the near future to a considerable extent, as supplies of the more popular grades of the metal are inclined to be short in supply. Consumption of tin in Europe is steadily maintained, while there has been a fair amount of buying from the United States of late. It is understood that negotiations are still proceeding between the Governments of the United States and Belgium for an exchange of American cotton and wheat for Belgian Congo tin.

According to Mr. W. H. Gartsen (Henry Rogers, Sons & Company), the total visible supply of tin on June 30 was 28,831 tons, as compared with 32,855 tons on May 31 last. These figures include the carry-over in the Straits Settlements and at European smelters (with the exception of the British Tin Smelting Company, Litherland).

Official quotations were as follow :—

Cash.—Thursday, £229 15s. to £230; Friday, £229 15s. to £230; Monday, £229 15s. to £230; Tuesday, £229 15s. to £230; Wednesday, £229 15s. to £230.

Three Months.—Thursday, £224 5s. to £224 7s. 6d.; Friday, £224 5s. to £224 10s.; Monday, £224 to £224 5s.; Tuesday, £223 15s. to £223 17s. 6d.; Wednesday, £224 10s. to £224 15s.

Spelter.—Under the influence of prevailing uncertain conditions the tone of this market has not been very bright of late, with buyers holding off from long-date trading. Good tonnages, however, are passing into consumption, with the galvanising industry continuing to lead the way in this respect. An interesting speech was that of Lord Horne at the recent meeting of the Zinc Corporation, Limited; he expressed the hope that a Cartel of zinc producers would be formed providing for the reasonable regulation of imports into the United Kingdom. Speaking of the future Lord Horne said that prosperity for them was governed by their production and the price they got for it. The programme of mine enlargement and re-equipment which they were just completing would enable them progressively to increase their output up to 750,000 tons of ore—or more—per annum provided that markets could comfortably absorb the resulting metals. Their immediate objective in the matter of output, however, was still 450,000 tons, which, in the absence of untoward happenings, they hoped to reach this year.

Daily market prices :—

Ordinary.—Thursday, £13 17s. 6d.; Friday, £13 18s. 9d.; Monday, £14 2s. 6d.; Tuesday, £14 1s. 3d.; Wednesday, £14 2s. 6d.

Lead.—The intrinsic position of this metal remains quite sound, although there has not been much buying recently, largely owing to the disturbed international situation. Consumption of the metal is still heavy and with this in mind Lord Horne, speaking at the meeting of the Zinc Corporation, Limited, queried whether it was necessary to continue the 10 per cent. cut in production or sales by producers outside the United States which has been in force for about seven months.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £14 8s. 9d.; Friday, £14 13s. 9d.; Monday, £14 8s. 9d.; Tuesday, £14 10s.; Wednesday, £14 12s. 6d.

Scrap.—Home and export business continues to be rather dull; as far as consumers at home are concerned the present is usually a quiet period of the year and it is not expected that there will be much improvement for some little time to come.

Approximate selling prices for old metal are unchanged, at :—New aluminium cuttings, £71; rolled, £62; cast, £31 to £35; foil, £80. Copper, £38 to £43; braziery, £36. Brass (clean), £22 to £25. Zinc, £9. Lead, £13. Gunmetal, £38.

Investigation and Modern Ideas on Enamel Control

(*Continued from page* 14.)

Company. Fig. 11 illustrates a gas-fired tubular muffle furnace for the investigation of the firing process in different atmospheres. A 2½-in. diameter silica tube forms the muffle chamber, and by a suitable arrangement strips of enamel can be fired and cooled under observation. When a normal ground coat is fired in an atmosphere of pure nitrogen, the enamel gathers like drops of mercury (Fig. 12) on the bright metal surface without any adhesion. If, however, the iron is pre-oxidised, the enamel fires down normally to give a coating free from gas bubbles (Fig. 13).

(*To be continued.*)